Johannis Hevelii Selenographia, sive Lunae descriptio; atque accurata, tam macularum ejus, quam motuum diversorum, aliarumque omnium vicissitudinum, phasiumque, telescopii ope deprehensarum, delineatio

[Selenography, or a Description of the Moon]

(1647)

by Johannes Hevelius (1611–1687)
Translation by Scott Weisman



Ars Astronomica
2026

"Johannis Hevelii Selenographia, sive Lunae descriptio; atque accurata, tam macularum ejus, quam motuum diversorum, aliarumque omnium vicissitudinum, phasiumque, telescopii ope deprehensarum, delineatio," published in 1647, is in the public domain. All translations, original additions, including illustrations, commentaries, and summaries, are copyright.

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Published by Ars Astronomica

Translator Version 2

Upright reason dictates that the recipients of the good, of whatever type and level of beneficence it may be, must show gratitude and blessing to the beneficent person in every way possible, commensurate with the value of the beneficence. And one who has benefited all the people of the world — for example, one who invented a new instrument for the good of the world, or a good book — it is fitting for every discerning person, out of the obligation of love of fellow beings, to at least purchase it, so that the man will profit and his heart will be encouraged thereby to invent yet more good instruments in the world. And similarly, all other wise-hearted people will likewise strive and exert themselves to invent good things and instruments needed for the repair of the world and its perfection.

And therefore, whoever says: "What do I need this new instrument for?" — he does not act well towards the world. For if not for the man who invented it, where would you be? And what would your city do? And more than this, if the man did not exert himself, what would the world do?

— R. Pinchas Eliyahu Hurwitz, *Sefer HaBris HaShalem* (1797)

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A note on the work

Johannes Hevelius, a Danzig brewer and city councillor, spent four years observing the Moon through telescopes he ground and built himself before publishing the *Selenographia* in 1647. It is the first lunar atlas drawn from systematic telescopic observation: forty engraved plates show the Moon night by night through its phases, followed by three full-Moon maps and an account of libration, the slow rocking that brings parts of the far side into view. Hevelius engraved the plates himself. The book also treats the appearance of the planets and sunspots, and closes with a method for grinding lenses and building telescopes. Many of the names he gave lunar features, borrowed from the geography of the Earth, are still in use.

The *Selenographia* was Hevelius's first major book. Riccioli's *Almagestum novum* (1651) introduced the rival nomenclature, named after astronomers, that largely displaced his.

A note on the translation process

This translation was produced with the translation-pipeline. See the linked repository for details on the process.

A note on the references. A scriptural or bibliographic reference given in brackets or parentheses is, in most cases, an **editorial identification of an allusion rather than a citation printed in the source**. Books of this kind quote and weave scripture constantly without naming it, and the identification is supplied here as a convenience to the reader. Where the source does print a reference of its own, it is given as printed. **An identified allusion is not evidence that the author cited that passage** — look at the original before resting an argument on one.

This text is the product of a highly refined automated translation process. It has undergone only cursory human review and should not be treated as an authoritative or scholarly rendering. It is offered solely as a reference and reading aid — a way to make an otherwise inaccessible work approachable — and any passage of real consequence should be checked against the original source.

Acknowledgements

The scanned copy used here belongs to the Austrian National Library (Österreichische Nationalbibliothek), which digitized it through Austrian Books Online and makes it freely available.

Translated with the assistance of Claude. The translator thanks the Anthropic team for making this work possible.

Notation and abbreviations

A few conventions have been applied uniformly throughout this translation, so that one quantity is always written one way. They change how a value is *written*, never what it is; where the printed source and this translation differ in notation, the source's own form is recorded in the editorial apparatus.

Numerals are Arabic, even where the source sets Roman ones. Roman numerals are kept only in headings, running headers and signatures, which are transcribed as printed.

Dates are given as year, month, day — *1572 November 11*. Dates are Julian, as the source gives them, and have not been converted to the Gregorian calendar.

Times are written with raised unit letters: $7^{h}\ 36^{m}\ 12^{s}$ for seven hours, thirty-six minutes and twelve seconds. An interval longer than a day carries a raised d — $3^{d}\ 7^{h}$. The degree and minute signs below are never used for time.

Angles are written with the conventional signs — 23° 27′ 30″. Early modern astronomy divides the degree sexagesimally and often runs to places for which modern writing has no common symbol; the orders used in this book are:

sign	order	the source's term
°	degrees	*partes*, *gradus*
′	minutes of arc	*scrupula prima*, *minuta*
″	seconds of arc	*scrupula secunda*
‴	thirds	*scrupula tertia*
⁗	fourths	*scrupula quarta*

A **sign** is 30° — one twelfth of the circle — and is written with a raised s: 5^{s} 3° 57′ is five signs and 3° 57′, that is 153° 57′. The source uses the sign both as a place in the zodiac and as a plain unit of 30° for a motion or a distance, and this translation keeps that distinction by writing the count rather than naming a constellation.

The signs of the zodiac. Longitude is reckoned eastward from the first point of Aries.

	Latin	English	longitude
♈	Aries	the Ram	0°–30°
♉	Taurus	the Bull	30°–60°
♊	Gemini	the Twins	60°–90°
♋	Cancer	the Crab	90°–120°
♌	Leo	the Lion	120°–150°
♍	Virgo	the Virgin	150°–180°
♎	Libra	the Scales	180°–210°
♏	Scorpius	the Scorpion	210°–240°
♐	Sagittarius	the Archer	240°–270°
♑	Capricornus	the Goat	270°–300°
♒	Aquarius	the Water-bearer	300°–330°

	Latin	English	longitude
♓	Pisces	the Fishes	330°–360°

The Sun, Moon and planets.

	Latin	English
☉	Sol	the Sun
☽	Luna	the Moon
☿	Mercurius	Mercury
♀	Venus	Venus
♂	Mars	Mars
♃	Iuppiter	Jupiter
♄	Saturnus	Saturn

Abbreviations used in table headings: **RA** right ascension.

Where a table in the source spreads one quantity across separate columns for degrees, minutes and seconds, those columns have been joined into a single column and the value written whole. Where a value runs to thirds and beyond, the columns are kept, since there the columns are the notation.

Binding: front cover of red leather, with a gilt border and a gilt armorial stamp; no lettering.

Front pastedown of marbled paper, carrying the later bookplate of the Imperial-Royal Court Library / Austrian National Library (shelfmark BE.5.H.28); not part of the book.

Marbled endpaper carrying a typed library slip (a list of the library's photographic negatives of this copy); not part of the book.

Blank flyleaf, water-stained; not part of the printed book.

Flyleaf, water-stained, carrying a later manuscript library pressmark at the head; not part of the printed book. The half-title on a following leaf shows faintly through the paper.

Blank flyleaf, water-stained, carrying only a faint mirror-image of the facing half-title; not part of the printed book.

HEVELII SELENOGRAPHIA.

Hevelius's Selenography.

Blank verso of the half-title; the half-title shows through in mirror image.

Diagram. Engraved allegorical frontispiece, filling the page. In a sky of clouds a crowned female figure, a six-pointed star on her brow and her robe strewn with eyes, rides an eagle and holds a long telescope. The eagle carries in its beak a scroll lettered *Contemplatio* ("Contemplation"). At upper left is a dark disc marked with spots, like the Moon; at upper right a bright, rayed disc crossed by two rows of dots. Below, two putti stretch out a ribbon carrying a scriptural motto. Beneath the clouds stands an architectural pedestal. On it two bearded, turbaned men flank a draped cartouche bearing the engraved title: the man at left holds a sheet with a geometrical diagram, the man at right a telescope. Under the cartouche two lions support a crowned shield charged with two crosses. On the base of the pedestal a scrolled frame encloses a view of a walled city with towers and spires on a river. The left pedestal is lettered ALHASEN. above a panel showing an oval object crossed by a curved inner line, and RATIONE. below it; the right pedestal is lettered GALILÆVS. above a panel showing an eye, and SENSV. below it. Engraver's lines stand beneath the border rule.

- Scroll in the eagle's beak: *Contemplatio* — "Contemplation".
- Ribbon held by the putti: "Lift up your eyes on high [?], and see who has created these things" (Isaiah 40) [Esai. 40.].
- Central cartouche (the engraved title): "Johannes Hevelius's *Selenographia*: or [?], a Description of the Moon, adorned with an accurate delineation both [?] of its spots and of its various motions, of all its other changes [?] and of the lunar phases, detected with the aid of the telescope [?], and with a rich supplement of celestial matters. Published at Danzig [Gdańsk], in the year from the birth of Christ 1647, at the author's expense, from the Hünefeld press."

- Left pedestal: ALHASEN. [Ibn al-Haytham] — RATIONE. "By reason".
- Right pedestal: GALILÆVS. [Galileo] — SENSV. "By sense".
- Bottom left, below the border: "Adolf [?]oÿ drew it" [Adolf [[B/D]]oÿ delineav.].
- Bottom right, below the border: "[?]. Falck [?], a Pole, engraved it" [[[J/S]]. Falck Polonus Sculps:].

Blank verso of the frontispiece; the engraving shows through in mirror image.

JOHANNIS HEVELII SELENOGRAPHIA: SIVE, Lunæ Deſcriptio

Johannes Hevelius's Selenography: or, a Description of the Moon;

and an accurate delineation both of its spots and of its various motions, and of all its other changes and its phases, detected with the aid of the telescope.

In it, at the same time, the natural appearance of all the other planets, together with various observations — above all of the spots of the Sun and of Jupiter — obtained with the telescope [Tuboſpicillo], are set before the eye in figures engraved on copper with the greatest accuracy; and also a great many astronomical, optical and physical questions are posed and resolved.

To this is added a new method of polishing lenses, and also a method of constructing and testing telescopes of various kinds; of making with their aid various celestial observations with precision, above all of eclipses, both solar and lunar; and likewise of determining the true diameters of the stars by an infallible route. In it, too, whatever else ought to be noted about observations of this kind is clearly explained.

With the grace and privilege of His Sacred Royal Majesty.

Published at Danzig [Gdańsk], in the year of the Christian era 1647.

At the author's expense, from the Hünefeld press.

Blank verso of the title leaf; the title shows through in mirror image.

To the glory of God, Best and Greatest, Parent of all things,

these Selenographic labours, worked out by lamplight with heavenly help shining upon them,

Johannes Hevelius gives, offers and dedicates

to the royal city of Danzig,

his fatherland, which embraces all our affections,

with a prayer for ever greater increase, for the sake of the honour and love he owes it.

Blank verso of the dedication leaf; the dedication shows through in mirror image.

Diagram. Engraved portrait of Johannes Hevelius, half-length, turned slightly to the viewer's left and looking out. He has long wavy hair, a moustache and a pointed beard, and wears a lace collar, a buttoned doublet and a heavy draped cloak. His right hand, in a lace cuff, rests on a stone ledge along the foot

of the image; his left hand is raised at the right edge and holds a small object. The background is densely cross-hatched. The image field carries no letters or labels. Below it, inside the plate mark, an engraved inscription in a calligraphic hand:

Behold the man who was the first to engrave the stars of heaven that he saw, strong in mind and hand, as no one had done before. You would bear witness to it, Ibn al-Haytham, if you were among the living; and you too, Galileo. Falck's most celebrated right hand has portrayed with the graver Hevelius, the noble star of his native soil.

— Johannes Mochingerus [Johann Mochinger]. f. [*fecit*, "made (this)"]

Helmich à [?]wenhuzen painted it. — Jerem. Falck [Jeremias Falck] engraved it.

Blank verso of the portrait plate; the portrait shows through in mirror image.

Ad Lectorem.

To the Reader.

We enjoy in this place an incomparable peace. The singular favour of God, Best and Greatest, has bestowed it on us, and the zeal of the Most Serene and Most Powerful Prince Władysław IV [ULADISLAI IV.], our Lord and King, by far the most clement, has preserved it — a zeal for the happiness of his subjects that is worthy of immortal praise. Since this is so, I have always judged that it concerns every one of us as much as anything can: that we should therefore give infinite thanks to the supreme Deity, and beseech Him most humbly that, together with the fame of His Sacred Royal Majesty, which is to endure for ever and to be most prosperous, we may long be allowed to be so blessed. In the same way it is, without doubt, our part to use this quiet, and the leisure granted us from heaven, so as not to pass in ignoble torpor a time that is favourable to everything. Rather, all of us, together and each one singly, should apply ourselves as best we can to promoting the fruits of peace, which are equally most useful and equally most praiseworthy. Then it will be publicly evident that we recognise so great a benefit of Heaven — one which most Christian regions have wretchedly lacked for many years now — and honour it with the spirit that is fitting. Although this was fixed deep in my very marrow, I did not, however, dare to persuade myself (measuring myself, as I knew was right, by my own small measure) that to that end

I could achieve anything more than some head of a household from the common flock and an honest citizen, or scarcely a little more than a private man. However, I was constantly engaged in contemplating the vault of heaven — a kind of study to which I always felt my mind strongly drawn from my tender years, both carried off towards it by a divine impulse and inclined to it by the well-judged and faithful care of my parents, in body and mind, whose memory I must always honour with the most grateful remembrance — and I was piling up observations begun long before. Then the thought came to me,

prompted, as I have no doubt at all, by a good genius, that it would be scarcely a commonplace undertaking, and would certainly be both very useful and not unwelcome to observers of the heavens [Uranoscopis], if I hunted out with my own sight, as far as I possibly could, the shapes of the planets, which are not yet sufficiently known, and, having perceived them somewhat more accurately with eyes and mind, set them out on paper for the world to look at. In this way all people too, driven by a divine exhortation, not to say command, might grow more and more accustomed to looking at the heavenly bodies.

The Moon, however, I judged to deserve attention before all the rest, because it seemed to have been observed less than it should have been. Moreover, I had concluded for certain that, once its variation — which up to now has indeed been believed to be uncertain — was rightly ascertained, astronomers, geographers, hydrographers, sailors and all people would reap a thousand benefits from it: if, that is, the true size of the lunar spots, together with their distance and proportion, as well as the fixed courses of the whole lunar body and the vicissitudes, were noted exactly and, once noted, were ready to hand, as if in a table.

When I disclosed this idea of mine to a few people, it was spurred on above all by certain men more skilled in mathematical matters, or at any rate more eager for them; their singular virtue and mutual affection I hold, most deservedly, as dear as my own eyes. Yet just as I found that my courage had been raised in this way, with the ardour to attempt the task growing beyond measure within my breast, so, once I had girded myself for the work (which day by day I understood would bring by far the greatest trouble), I came within a little of giving way under the burden. First, a telescope [Tuborum aliquis] had to be sought — something one cannot do without here — and not one ready to hand in the market and in the shops of goods for sale, but a choice one, which the heavenly bodies would admit and not elude. But where, and from whom, I ought to obtain it, I could not discover. Next I realised that whoever took on this labour had to assume the role of Endymion, celebrated in fable, and must for the most part sleep by day and stay awake for the greater part of the night — which could not be done without no small weakening of bodily strength, nor without the loss of many things. From this a far greater fear still arose: that one could not even dream I would find a companion in these labours, by whose help what was seen might be committed to paper, but that I alone, by myself, would have to bear both the care of observing through the night and the daily care of recording — that is, eyes by night and hands by day in perpetual occupations. Yet all this was nothing beside the thought that presented itself to my mind: how great the difficulty would be of bringing so rare — indeed so unattempted — a work to some conclusion that would please, whether me alone or others too. But in the end I steeled myself, turning over in my mind not so much this: "a way must be tried by which I too may raise myself from the ground", as this: what must not be done for the glory of God, with whom, if He so wills, we can do all things? So, having humbly implored His help, I set about the task eagerly.

My first concern, before all else, was to acquire telescopes [Tubofpicillis]. But what could not be bought with money was made with our own hands and sweat. So I had to play the craftsman before I could play the sky-watcher [Cœlifpicem]; for without these ladders I would have been denied the climb into the dwellings on high. When I had built them as I wished — indeed beyond my wish or expectation (for how could I have promised myself that here, as the saying goes, I would hit the nail on the head?) — I gave myself wholly to turning well-armed eyes on the heavens and, like some explorer, penetrating the regions of all the planets, and above all of the Moon, in order to know them more intimately. Fate and effort found the way. Saturn, so very hidden at all times, was observed; the attendants of Jupiter, its retinue as it were, were noticed, and Jupiter's own spotted face; Mars, with its true shape, and noted as to its light with its waxing and waning; the palace of the Sun, surveyed as much for the light of that fruitful parent as for its various spots and faculae [faculis]; the phases of Venus and Mercury were seen; and some fixed stars were detected, hitherto unseen and unexplored. In the study of the Moon, however — to which I had resolved to devote myself above all, thinking it worth the effort — I lingered and persevered with all diligence. In this way I grasped with eye and mind its various full moons and quadratures, and forty of its faces; and, having grasped them, I took the engraver's burin into my own hands, drew them, and fitted out this paper heaven, as it were, which now comes forth. Those who pay even a little attention will value this labour at its proper worth; but the spirit behind it, I think, all will value far more.

Yet even so I was not free of every care: I also had to take on the part of a name-giver and, for the sake of distinction and of the better understanding that distinction guides, give fixed names to the lunar spots, so diverse as they are. Harder than that task was this: that the librating motion of the Moon's centre and of its horns, together with the limits and inclinations of the full moons, quadratures, trines and all the remaining phases, and other things of this kind perceived with wonderfully favourable success, should be bound to fixed laws in keeping with nature, with their use shown to all. When all this had been completed and, as is my custom, shared with friends, I was urged on still more keenly to oblige the public, and a Selenography, in which all my observations were to be gathered together, to bring it out into the light: partly to tell forth in this way the glory of God together with the heavens; partly to offer all the inhabitants of the Earth, of every nation, who would read this Selenography or at least look at it, such things as might grow to the greatest common benefit; and further to give mathematicians a spur, so that they might undertake celestial observations more accurately than ever before, and to carry before them a torch by whose light the perpetual tables of the celestial motions might be made more perfect, and a way found of investigating the longitudes of places more skilfully — to say nothing of other things. No sooner said than done. And above all, admonished as it were by the stars and lights of heaven that I had so often looked upon, which shine — or are of use — not for themselves but

for others, I took the lamp into my hand. I also had this further in view: that no Selenography had yet appeared among so many -graphies of who knows what kind. So, taking up the pen, I have written out to the best of my ability the Selenography that I now hand over. In composing it I did not seek an order far afield or anxiously; rather, the order that pleased me was the one that offered itself of its own accord at the outset of the work I had undertaken, and that constantly surrounded me while I was occupied in handling the matter itself. Therefore, at the very threshold of the Prolegomena, we have set out first, briefly and yet clearly — as we at least believe — certain things on lenses of various kinds and their polishing, as well as on the construction of telescopes, the way of testing their power, and other matters pertaining to this: since celestial contemplations (as is well known) can by no means be carried out without the aid of optical tubes. Next, we have also given a kind of guidance on how telescopes ought to be properly directed at the stars and used with the eye, adding whatever has so far been discovered, whether by others or by myself, with the help of such spyglasses [Perspicillorum] rightly applied. But among other things we have set out to report faithfully what it was possible to notice in observing the fixed stars and, above all, the planets — with an accurately drawn picture of them, which we present at the same time, and with questions of every kind that seemed most to bear on this added and resolved. On the same occasion we have likewise discussed, as clearly as could be done, the motion and properties of the Jovials [Jovialium], as well as the solar spots and faculae. I say nothing of what will be set out at length in its place concerning observations of the fixed stars, and especially concerning the Vladislavian stars [stellis Uladislavianis], which Antonius Maria de Rheita [Anton Maria Schyrleus de Rheita] chose to call the Urban-Octavian stars [stellas Urban-Octavianas] — without concealing our own judgement, such as it is, on these same stars: whether they should be assigned to the order of the wandering stars or of the fixed. To these are added airings and discussions of many more other matters and opinions, neither unpleasant nor useless. These things, touched on so briefly here, the Prolegomena present at length. Now in the Selenography itself, at the outset, both of the ancients and of the more recent philosophers, we have brought onto the stage all their various opinions on the Moon and its spots, and on the way in which it receives and returns light: the erroneous ones we have lightly hissed off, while the true ones we have set out to commend more and more with our applause. We have further treated the various motions of the Moon, both those found out hitherto and those noticed now for the first time; these we have placed in a fuller and plainer light, so that the lunar phases and faces displayed in order in the volume itself might be grasped all the better. And then, finally, we have set the phases themselves before the eyes of all, with a necessary explanation, and with notes and questions pertaining to the foundations of mathematics as well as of physics and optics — with some apparatus, as it were, or display [apparitur̂a]. And so, last of all, we have shown lovers of the stars [Astrophilis] the use of this Selenography of ours, indicating

above all, namely, the new and infallible method by which everyone may easily observe both eclipses and occultations of stars and the longitudes of places (the one goal, I confess, at which our work aims); this we have also illustrated with several examples, indeed neither common nor obscure. In this way, that is, the road useful for all celestial contemplations — a road truly royal and outstandingly safe — has been levelled. And so, my reader, you have received the idea of our work, sketched in very few lines. If you burn with desire to see it whole, come, if you please: all its pages, either you will turn over or fly through, so that whatever you judge most worthy of your study you may weigh more carefully and embrace more firmly in your mind. It is certainly not for our own glory that we have sown here, and so we burn with no desire to reap it. It will be enough if — what we most wish — the admirable power, magnificence and goodness of the Parent and Founder of all things shines out to you from here. If that happens, give thanks to God that he has deigned to reveal these things to each of us: to me, as I search them out with laborious toil, and to you, as you enjoy them at leisure without it. And indeed, if you also wish us well, you will join me in imploring God that he graciously preserve and increase the spirit he gave me — to search eagerly into these mysteries of his, contained in the volume of the heavens, and eagerly to make them known — kindly granting also the soundness of body that is necessary for this too. For then, furnished with strength, and helped by the fairness and goodwill of readers if we meet with it, we shall certainly rise far more eagerly to pursue this road and to spend our life for the public good, once we have rested for only a little while. If, however, anyone has certain things to hand, whether of this stamp or of a better one, we ask him not to keep it hidden but to bring it into the light, however much our own work might be obscured by it. There is one splendour of the Sun, another splendour of the Moon, another splendour of the stars; for star excels star in splendour — as St Paul rightly notes in 1 Corinthians 15:41 [Ep. I. ad Cor. C. 15. v. 41.], and as experience attests, as does this present slight little work of ours.

I wrote this at Danzig, in the year from the birth of Christ 1647, on May 6 [pridie Nonarum Maij].

Honoratissimorum Amicorum sponte exhibita Carmina.

Poems freely offered by most honoured friends.

In Opus Incomparabile Amplissimi Viri Johannis Hevelii.

On the incomparable work of the most distinguished man Johannes Hevelius.

Mighty souls, whom the tireless and keen, restless labour of knowing all things drives on, learn, after everything else, the splendid book of Hevelius, a work of astonishing and arduous endeavour. Here, after the arts have so far been happily exhausted, you behold new springs of the sciences. For having searched Olympus with a bold glass, and roamed the stars with lofty step, he

now sets before our eyes worlds hitherto unseen, extending the boundaries of the vast universe — Hevelius, the new glory of Danzig. Whoever, wherever you are, you who now favour unaccustomed endeavours, venerate with me the genius of the ethereal Columbus, the man worthy of his fatherland, and the fatherland worthy of the man.

Vincentius Fabricius.

In Auctoris Ingeniosissimi Laboriosissimum Opus.

On the most laborious work of a most ingenious author.

Once Jupiter marvelled at the Syracusan's spheres: all the gods marvel more at this, a work of Danzig art! Saturn, the Titan, Mars, Mercury and Venus — how Cynthia is seen, engraved by a learned hand! Jupiter too, with the Tuscan stars, is shown spotted; Prussia now yields nothing in praise to Latium. Whether it may surpass it by new ventures is now the question: this dispute, Apollo, demands your judgement.

Made for an old friend, gladly and deservedly [L. M.], by Benjamin Engelke.

De Utilitate hujus Selenographiæ

On the Usefulness of this Selenography.

A poem by Laurentius Eichstadius [Lorenz Eichstaedt], D. P. & P. G. G., poured out with dutiful affection and applause.

It is no easy thing to climb the summit of Olympus, to learn the various motions and positions of the stars, and rightly to count the degrees and times of the heavens. Few mortals indeed — those whom just Jupiter has loved, or whom ardent virtue has raised to the aether — can accomplish this, and touch the Moon with their heads. You, Hevelius, the sweet Muses took up before all others; they taught you rightly the paths of the heavens, the courses of the stars and their numbers, and how great their bodies are, and showed you at the same time the difference between light and shadow; and Urania breathed into you the love of the heavens. Strong in this power, you undertake lofty ventures: diligent, you survey the winding folds of the bright heavens, and also, with fine instruments, you range over the Moon's different faces, and review its spots, and whatever new thing the monthly Moon forever brings forth: what aspect, what change, how great from time to time the Moon's is; how it varies its face, and varies its figure; how, when new, it shows itself sickle-shaped, soon halved, then gibbous, and also the orb of full light. And you mark all the spots with a name from this Earth of ours, and measure their mountains by shrewd reasoning. That road was not known to the astronomers of old: in our age the optical tube [Tubus Opticus] has uncovered it, made with skilful art, as dioptrics properly teaches. See — through your labour, Hevelius, devotee of Urania and priest of Phoebus, we now begin to observe more correctly the labours of the Moon, and its frequent eclipses; now too the places of the lands, set far apart, will stand at fixed degrees better than before. Soon, too, the

practice of navigation will rejoice to have hydrographic charts formed from better clay: for great is the fruit and the use of Selenography. All this you have given to the eyes to be finely viewed in the present book, as in a living image; for you add emblems adorned with wonderful forms, which have surely been drawn out with great labour, and with wakeful study by night, and study by day. Moreover, rising higher, Hevelius, you go on, skilfully and in right order, to pass through the remaining fires: for from here you draw down from the heavens the blazes of eternal light, and show the Sun on a small tablet, and the spots it drags with it, and the faculae that follow, which turn about the Sun's axis from its rising towards its setting, you show by wonderful inquiry. So too we are taught here to observe correctly, on a small tablet, the eclipses of the Sun, plunged in great darkness. Moreover you represent the sickle-shaped face of the star of Venus and of Mercury, and their faithful form; what the ruddy fire of Mars, too, is always like; what the companions of Jupiter are, and how many they are in number; by what method one may tell them apart from the other stars that also stand at times around Jupiter's star; what the face of Saturn is, and the double handle by which it seems to represent a triple star. You add the small lights of the innumerable fixed stars, and their whole mass, which a fitting optical instrument [dioptra] discloses; and you set at the front, too, a truly outstanding *Dioptrics*, such as neither Ibn al-Haytham nor Vitellio [Witelo] knew. The learned will now credit these things to you as their master, and grateful posterity will recognize your labours, and from this will assign you, without envy, a lofty seat among the mathematicians famous in this age, and will say without doubt, and confess with candid mouth: "This man endured much and did much, he sweated and he froze, before he caught all your spots, Phoebe." So it comes about that Galileo is not to carry off the first prizes of so great a praise, nor Scheinerus [Christoph Scheiner] claim the next for himself: one man holds both the first and then the second. Hence the work deserves to be set up in the sacred temple of Fame, where it will stand as long as Cynthia shines in the heavens. Therefore despise the other, profane cares of men; do not even heed the rash judgements of the crowd, nor set great store by the sour voices of the idle, who laugh at these studies and refuse to touch heavenly things. For gain, ignorance and luxury harass them, ambitious honour, and wealth, and foul pleasure, which draw them back from heavenly ventures and thrust them down to the lowest things. Therefore, O Hevelius, no degenerate dweller in the world, a blessing on your labour, and a blessing on your divine talent! Go on, as you have begun, to lay down the laws of the stars; the love of fame and of virtue will lift you up, borne higher than the breezes of popular favour, on swift wings; at the same time great Copernicus will feel your help, ready to hand, and the cult of the stars will grow and endure; and you will spread far and wide the love of talent and of wisdom, while through you the supreme wonders of JEHOVAH are laid open, while all the sights of heaven, as the stars come round again, go back to their own seats, set back in place with wondrous art. Breathe favour on this undertaking, Ruler of great Olympus.

In Selenographiam Viri Celeberrimi Dn. Johannis Hevelii Scabini apud Dantiscanos Honoratissimi.

On the Selenography of the most celebrated man, Mr Johannes Hevelius, most honoured Lay Judge [Scabinus] among the citizens of Danzig.

Do you long to learn the greatest wonders of the starry universe, and what changes it unrolls in turn? Do you wish to see the lights of the Sun, glowing red with shining rays, and the black marks with which they are spotted? Do you wish to know the varied figures of the inconstant Moon, and what it shows, then, in its full orb? And the many things hidden from past ages and never told, which have been disclosed here in splendid ways? Now it is a delight to lift one's eyes to the seats above: what mighty maker could have founded these for the lands? Look at the shining tents of the star-bearing heaven, and marvel at the astounding works of your God. To see vast tracts of regions in the Moon — who would have believed there were huge gulfs of sea there? Who would have looked for black spots in the bright light of the Sun? Or said that the Earth goes wandering? Who would have thought that the star of Venus waxes and wanes, as does your retreating star too, son of the Pleiad? But these marvellous chased works of the star-bearing universe the noble work of the famous Hevelius lays open. Hevelius, a Daedalus of keen talent, now brings forth what outstanding men could not before. Argus with his hundred eyes watched in every direction; but Hevelius sees more with a single tube. No one has marked your labours, Delian, or yours, Cynthia, with a more attentive mind than this man. Ever wakeful, he detects the innumerable fires of the aether, and stars that were never seen before, and he has brought the distant stars close to our eyes by the dexterity of the art of a new invention. Atlas did not carry the heavy axis of heaven to the end, Jan [JANE], but laid such great weights on your shoulders. Hence your glory will shine through endless ages, as long as there are stars, with Phoebus and with Phoebe.

Set down deservedly and from the heart by Gerbrandus Hajo, Doctor of Medicine, of Danzig.

In Selenographiam Hevelio-Gedanensem, Ad Autorem Clar. & Ingeniosissimum Epigramma.

On the Danzig Selenography of Hevelius: an epigram to its famous and most ingenious author.

Hevelius: the dispute is whether the palm should be yours or COLUMBUS's, and whose genius nourishes more vigour. You pierce the air, he furrows the seas; you range over Olympus, he circles the poles of the world. You mark the faces of heaven, he the shapes of the Earth, unknown until now: he by ship, and you by tube. You show spots, faculae, mountains and rivers, and many more wonderful configurations of the Moon's torch. He uncovered harbours and new lands and rivers, and many broad climes of the terrestrial globe. You

reveal by what natives the shining Phoebe is inhabited; he, the Indians and the fierce Cannibals. In sum: each of you has made new worlds manifest, little known before, with equal usefulness. Hence, then, the dispute: should the palm be yours or COLUMBUS's, and whose genius nourishes more vigour? Who will settle the dispute? I will say what I think: the palm befits both of you (for you are equals in your pursuits). That famous Daedalus lived, and so (as we know) did Apelles, and shrewd Euclid: you too triumph as one of their kind. Whether a machine is to be built, or metal engraved with the stylus, or things set down in painted marks, or those things demonstrated with mathematical figures, you alone are strong in all of these, in mind and hand. Indeed even the copper-engravers have seemed to yield first place to you, since they cannot reproduce your plates in copper. And, what is the head of the matter, the fruit of both discoveries will be a hundredfold for anyone who only knows how to use them. Misuse brought very many evils upon the world of COLUMBUS; I fear nothing of the kind for the globes of HEVELIUS. Why should I recount the rest? You, HEVELIUS, are equal to COLUMBUS, and he to you: for in merit you both rise as equals, worthy that the ninefold throng of the Muses, and Posterity too, should set up statues and such monuments to you. "Let the palm be equal for the daring ventures of Hevelius and of Columbus: for the genius of neither lacks vigour!"

Congratulating the commonwealth of letters on its new growth, and the most sagacious author on the growth of his fame, I wrote this at Elbing [Elbląg], CYPRIANUS KINNERUS [Cyprian Kinner], D., Councillor of Liegnitz [Lygius].

DE BORUSSIA: ejusqúe indigenis tribus, NICOLAO COPERNICO, PETRO CRÜGERO, JOHANNE HEVELIO; Mathematicis, ad unum, omnibus excellentisſimis.

On Prussia, and on three of her native sons, Nicolaus Copernicus, Petrus Crügerus [Peter Crüger] and Johannes Hevelius: mathematicians every one, and all of them most excellent.

Our Prussia counts three cities, together with Königsberg [the King's Mount], as her chief. That one, venerable with age, Thorn [Toruń], is first; then cultivated Elbing [Elbląg], second; third, Danzig, more than three and four times blessed. All of them cities that flourish on more than one account, and there is no need now to tell all their endowments. Let it suffice to have touched on this: that the one, and the other, and this one here, each by its own right, holds its head high on account of certain citizens, strong no less in virtue than in knowledge. Among these, surely, are men born under a lucky star, at whose nightly labours the stars themselves have marvelled, while they search out the course and the remote regions of the heavens. Thorn brought you forth to the world, great Copernicus; you, Crüger, excellent Königsberg gave to the world; Danzig is the native city of the most ingenious Hevelius. Come, our Elbing, bring forth a star-sage too, equal to your poet Zamelius [Gottfried

Zamehl], renowned for his lofty song. And so, my Prussia, grow in praise of every kind: you who now flourish in peace, may you long enjoy peace!

Johannes Mochingerus [Johann Mochinger].

Cease, Danzig, to mourn the fate of your Crüger, who, with a wonderful dexterity of art and genius, searching out the heavenly mansions and the recesses of the stars, carried his name above the stars and spread it through the whole world, a name to die at no time. No less did he himself bring your name to foreign shores, to endure no less than Crüger's writings, which will long endure. Cease, Danzig, to remember your past grief: only the ending of his service in office begets this grief in you, and the fatherland itself claims for itself a share of the man's praise. Now rejoice the more: more splendid monuments of an eternal name are being prepared for you. Who before this has pierced the byways of the heavens with so watchful a keenness of sight, and come to know the spots of the Moon so well that he has dared, up to now, to give each its own fitting name, as this native son of yours? Him the gentle grace of his manners sets before the citizens as a mirror of an honourable life; for him candour and probity have earned a place, by the Senate's vote, among the honoured lords of Themis; and him heavenly learning, and the new Tube for seeing the wonders of the sky close at hand, places among the keen astronomers [Aſtrologos] and the cultivators of mathematics. Olympus itself rightly congratulates itself, and justly gives you thanks for the gift of so great a citizen, who now opens its dwellings, long hidden from the mortal world, and shows the way by which the glory of Heaven may become better known to the earth-born, and the wonderful works of the gracious Creator be adorned with worthy honours.

[Margin: G.] Blessings on you, man, for the gifts of a happy genius! See: by these and by unremitting labour it has now fallen to you alone to bring forth for our age a work of such great light, one not seen by ages past, which snatches the palm from those to come, forbidding them to strain the sinews of genius in this direction. Give way now, you Arabs; give way, Chaldaeans, seers of Egypt: HEVELIUS disperses all the clouds with a new light, leading the eye into the inner sanctum of Heaven. May the heavens decree you long threads of life, so that you may add greater things to what you have begun, and for yourself double your pleasure by contemplating, and by writing leave a lasting name among the nations, until above, not beneath, the heavenly lights, you see the Light of the Author of light, without a glass and without end.

Michael Borck, Secretary.

Clarisſimus HEVELIUS Germaniæ EV-HELIUS.

The most famous HEVELIUS, Germany's EU-HELIUS [good sun].

So that man, who is dust, may lift his upturned face to the STARS and join in celebrating the glory of the CREATOR, HEVELIUS kindles a light in the midst of the shadows, and becomes a light in the world, a [Greek: Ευ-ηλιος (eu-hēlios, "good sun")] HEVELIUS. Come! Go on, HEVELIUS: with your

learned hand clear the darkness from the paths of the SUN and the recesses of the MOON. So HELIA will marvel at your Daedalian ventures, and the land SELENA will sing of her own ichnographer [Ichnographum].

In the year in which HEVELIUS, born on the shores of Danzig, the first selenographer by his art, rightly prepared his work.[1]

With the congratulations of Abrahamus de Frankenberg [Abraham von Franckenberg].

In Selenographiam admirandum admirandi ingenii opus, Nobiliſſimi, Amplisſimiq́; VIRI Dn. JOHANNIS HOEVELII, auguſtæ Reip. Ged. Scabini prudentisſimi.

On the Selenography, the admirable work of the admirable genius of the most noble and most distinguished man, Mr JOHANNES HOEVELIUS, most prudent alderman of the august Commonwealth of Danzig.

JOHANNES HOEVELIUS, an anagram: Behold, you are the Sun, the pearl of the age.

While you honour Phoebe, the Sister of Phoebus, with the honour of Phoebus, HEVELIUS, you depict her genius too with your own genius and your ray; Fame the messenger carries the work of a divine mind to the summits of Pindus. When a council of the Aonian Muses has been held, she asks with what praise the Author is to be borne aloft, and of what honour he is worthy. At once the Sisters cry out with one voice: "He is worthy of the ages; he is worthy of the honour of cedar." Then Apollo summons you to himself and addresses you thus: "You are the Sun of the age, HOEVELIUS, and its outstanding pearl. Fame, surviving, will carry you and your monument to the eastern and the western dwellings of the world." He spoke; and, bringing out the book of eternal Fame, he inscribed you and your work in cedar that will live.

Johannes-Georgius Mœresius, Rector of the School of Saints Peter and Paul at Danzig.

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[1] the full capitals of these two lines form a chronogram, V L I V V D I I M V I I L V I V V I V, summing to 1647.

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SELENOGRAPHIÆ CAPUT I.

Prolegomena to the Selenography. Chapter I.

On the various glasses that are usually used for optical tubes; on the marks of a good and of a faulty lens; and also on the true method of making the best ones, briefly set out.

If ever at any time the sciences and faculties have been cultivated and have grown from day to day, this can certainly be affirmed of the present. In our time not only the various disciplines but also the mechanical arts have been enriched by the most ingenious and skilful men with solid growth, with new additions and with most excellent inventions — inventions that not only arouse

great admiration and delight in the minds of people eager for knowledge, but also bring outstanding usefulness. [Margin: In our age the disciplines and the mechanical arts have grown enormously.]

For — not to go too far back — let me speak for the present only of that cheap and lowly material which is fused from sand and ashes. How few indeed of the rough and unskilled common people, who have never before seen this craft, could be brought to believe that from sand, or sandy pebbles and ashes, or a salt-like earth, there is produced a material so fine, pure, compact, hard and durable, and yet clear and transparent — the material we usually call glass, and which we know to be on sale in such abundance that large pieces can be bought for a small price?

For my part I am entirely convinced that, if in this age of ours glass were not found in such abundance, nor made by common people with so easy a craft, but had, for want of it, to be fetched from the most distant lands, it would be far dearer, and would be preferred to very many other precious things; and that not so much for the reason that this same glass, for necessary and useful household things, namely for mirrors, cups, cucurbi-

ts for distillation, windows and similar things, that it is sought after, but chiefly because it serves the investigation of abstruse mathematical matters, through which the tireless explorers of nature are led to a knowledge of natural causes further removed from our senses. [Margin: Glass is extremely useful for investigating various matters hidden in nature.]

We owe a great deal, above all, to the most skilled and most perceptive mathematicians and opticians — among them, by name, to the Arab Ibn al-Haytham and to Witelo. The former in his seventh book, the latter in his tenth, set down in writing and handed on to posterity that excellent doctrine of refractions, showing no less adequately than clearly that rays projected into a rarer or a denser transparent object are refracted either away from the perpendicular or towards it; that by such refraction the angle of vision is either contracted or dilated; and that visible species [species visibiles] are seen either more remote or nearer, or else smaller and larger — as we too shall explain more fully later on this whole subject. [Margin: Ibn al-Haytham and Witelo, not the least, who demonstrated the doctrine of refractions.]

At first sight, indeed, this doctrine does not appear to offer what it afterwards delivers on closer acquaintance. I readily grant that the eminent ancient opticians named above did not foresee that as much usefulness would flow from that demonstration as infallible experience later proved. For in the course of time this oak was shaken by many blows from sharper minds; and, driven by a mind continually intent on the matter and after trials made in various ways, glasses either concave or convex were skilfully worked to a definite segment of a circle. These are of use in many ways to that noble and wonderful member of the human body, the eye: they not only strengthen and preserve its vigour, but so perfect its sharpness that with the help of such glasses things become visible that could not before be grasped by sight that was naked and not armed.

[Margin: Convex and concave lenses took their origin from the doctrine of refractions.] [Margin: Lenses serve the eyes in many ways.]

This is therefore a truly excellent and ingenious invention indeed. Such glasses wonderfully promote and enlarge the use and the actions of human eyes, which you would most deservedly count among the very chief members of our body. [Margin: The eye, a principal member of the body.] We use our eyes for the contemplation of the wonderful works of GOD:

and our eyes are also the guides of almost all our actions. In their praise Chrysostom, in his 55th homily on John, said most rightly: *"What the Sun is to the world, the eye is to the body. When the Sun is extinguished, all things are lost and thrown into confusion; so too, when the eyes are lost, the feet and the hands are useless. Therefore the eye has been allotted its seat as in a royal place, in the higher part of the body, and it is preferred to the other senses. The eye, the lamp of all the members, adorns the whole body."*

Hence it cannot be otherwise than that, as we were just saying, the labour spent on glasses fit for making dioptrae [dioptras] is an outstanding one, since they contribute so much to the eyes, beyond dispute the most excellent parts of our body. As a result, many learned men have not been reluctant to lead the way, by example and by their own work, for the sedentary craftsmen who make spectacles. [Margin: Working lenses is a notable labour.]

The form of lenses, however, varies. First, some lenses are uniformly plane and polished. 2. Next, others are plane on one side and either convex or concave on the other. 3. Further, some are convex on both sides, and concave on both sides. 4. Moreover, some are mixed: concave on one side, convex on the other. And these in turn come in three varieties: they are either spherical, or elliptical, or hyperbolic. 5. Besides, these lenses can also be prepared from one segment on one side and from another segment on the other, as regards both the convex and the concave form. The proportions of the segments according to which the lenses just mentioned can be formed are not only innumerable but almost infinite, as anyone who has learned from geometry the variety of the segments of a circle readily understands. [Margin: The form of lenses varies.] [Margin: The differences of lenses.]

As for conical, elliptical and hyperbolic lenses, I shall give only this brief and general note about them. Although lenses of this kind have been exquisitely demonstrated in optics, nevertheless, because so far as I know they have not yet come into view and use, I shall therefore pass them over, mention only spherical lenses, and show their use and the way of preparing them. [Margin: Conical lenses sufficiently demonstrated indeed, but not yet perfectly worked.]

The first kind of lens, which is uniformly plane on both sides, can provide spectacles solely for young people who are still endowed with good sight and wish to preserve and strengthen it. The remaining lenses, both concave and convex, [Margin: The use of the various lenses.]

not only serve older people who have lost the sharpness of their eyes, and the dim-sighted, for making spectacles from them; they are also suited to the

various kinds of optical tubes, to burning glasses, to glasses that extend the sight, and to the glasses fitted to the opening of a darkened chamber, so that objects visible outside are represented clearly and distinctly inside on a white board — not only in inverted order, as usually happens, but also upright again, by means of the same lenses — and to a good many other uses, of which there will be occasion to speak later.

Among convex lenses above all there is no small difference. First, the less convex they are, and the larger the segments from which they are worked, the less they enlarge the angle of vision, if spectacles are to be made from them; and so they suit the spectacles of younger people, whose sight is not yet dull. But the more convex the spectacle glasses are, and the larger the segment to which they are worked, the more they sharpen the sight, and they are best suited to older people who suffer from weakness of vision. [Margin: Great difference among convex lenses.]

But the principle of the lenses used in telescopes is quite different. For the more convex lenses are required to dilate the angle of vision and enlarge the visible species, the less raised they must necessarily be, and made from a larger segment. Furthermore, it should be known that plano-convex glasses enlarge the angle of vision twice as much as those convex on both sides, and that they give a tube twice as long. The same principle also holds for convex lenses used in darkened rooms to present the species of objects outside: the flatter the convexity, the larger the figures they render, and at a greater distance they show them; conversely, the more prominent the convexity, the smaller the images they produce, and at a smaller distance they show them. [Margin: Convex lenses produce a far different effect in telescopes and in dark chambers.]

Similarly, as regards burning and kindling glasses, which are commonly made convex on both sides: the less they rise, the farther off they burn the objects, and the more they enlarge letters from a distance; on the contrary, the more they rise, the nearer they burn, and the nearer the glass must be brought to letters being inspected. For, that things in this way, [Margin: The difference among burning glasses.]

and not otherwise, stand, anyone eager to investigate the matter will learn for himself by reliable experiments.

It should also be noted here that a plano-convex lens, worked from a spherical segment whose diameter equals twelve feet and polished in the proper way, will present objects visible outside distinctly and clearly in a darkened room, at a distance of about 12 feet from the opening — provided only that the opening is neither too wide nor too narrow. For if the opening is larger than it should be, the images fall too dull, because of the abundant light spread around them; but if the opening is smaller than it should be, the images are represented more obscurely on the paper-covered board, or on a linen cloth well whitened and not very permeable. [Margin: With the help of a certain lens, species visible outside are painted distinctly in a darkened room.]

All this will be presented to the eyes more distinctly and with greater clarity if, in place of the paper board on which the figures are shown, you use a concave mirror, either spherical or parabolic; or, if this is lacking, a large glass convex on both sides, or convex on one side and plane on the other, covered with foil on the convex side so that the species cannot pass through. [Margin: A way of representing the species still more clearly and distinctly.] For a glass of this kind, if it has been properly prepared, will do almost the same as a spherical concave mirror. For if the visible species are received on such a glass, you will find that they are presented in the same way, and in inverted order, as happens on a board, a cloth, or a wall; no less. As the opening of the window is reflected in this mirror, it must then be moved this way and that until the figures shown outside appear through the opening of the mirror and of the window — which will happen as desired if the angle of incidence corresponds to the angle of reflection. In this way the visible species falling in from outside will not only present themselves with upright face and figure, but will moreover appear as clear and distinct as if you had looked out of the room through an excellent telescope and viewed the objects themselves; this will give great pleasure and will be a wonderful sight. So too, by means of this mirror, images can be displayed on the wall of the room in whatever part one pleases.

But if a mirror of this kind is lacking, upright figures will also fall onto the board through a burning glass convex on both sides, if it is drawn away from the eyes towards the board; or, if through a twin burning lens, mutually [Margin: Visible species that are inverted can be made to stand upright in various ways.]

matched and set in order at the proper distance, the visible species are received. In the same way, visible objects are also made to stand upright by two convex glasses turned from a small segment — the kind that suit older people — fitted to a small tube. For if these glasses are enclosed in a tube and suitably adjusted to one another, as their proportion requires, then the visible species too will be seen upright on the board.

And yet we could easily do without these methods, just described, of representing figures in upright form, if it were possible to make a glass from a hyperbolic segment. For such a glass, brought to the opening, would show all visible objects, in their true and upright difference of position, far more clearly and distinctly than spherical lenses — as those most learned opticians Renatus de Cartes [René Descartes], Marius Bettinus [Mario Bettini] in the *Apiarium Mathematicum*, and others have demonstrated amply enough. [Margin: The best way of representing objects and setting them upright: namely, by a hyperbolic glass.]

As for the making of convex lenses, they are usually worked and polished as carefully as possible in a copper dish, from some definite spherical segment. Concave lenses, by contrast, are made with no less care and skill on an exactly turned globe, whether it be of iron, bronze, or brass, as those know who have

put their hand to this work at all. [Margin: The making of convex and concave lenses.]

But if those who are untrained and inexperienced in making glasses of this kind want fuller instruction, let them consult Hieronymus Syrturus [Girolamo Sirtori], who has written fully on this subject and on all the apparatus it requires. The method of working glasses in the dish and on the globe just mentioned can, however, be undertaken in different ways. The common method, which Sirturus and almost all the other craftsmen to a man employ, is done by free hand. Another method of making these lenses is also adopted, on a bench and turning-machine; on it, however, only concave lenses are turned and polished. Whether convex lenses too have been worked on a turning-bench or not, I do not know. Therefore, for the benefit of lovers of this craft, an invention — not to be despised, in my judgement — of a special turning-bench, on which to turn not only many other things, as is commonly done, but above all such lenses, both convex and concave, and other glasses, by a thoroughly expeditious and [Margin: Description of a special turning-machine for making lenses.]

Diagram. Full-page engraved plate, inscribed *fig. A.* at the lower left: a lens-turning bench set up in a room with a beamed ceiling and a leaded window. A long flexible pole runs along under the ceiling beam, held by two hangers on the right, and its tip on the left is tied to a cord that drops down past the window to the machine (a spring-pole drive). The bench is a long plank on posts. On its left half a horizontal turntable disc with upright pins is carried on a vertical spindle, driven by a cord over a pulley; on its right half an upright block carries a horizontal lens-holder adjusted by a screw with a knob, with a long rod running from it out past the right end of the bench. Both ends of the bench are clamped by screw-headed blocks to tall posts. Below, a board with a semicircular notch is fixed between the posts, and on the floor lie loose parts: a treadle bar on an upright, a hemisphere set in a block, two flat grinding plates with knobbed handles, a hollow cylinder, a toothed ring, a slotted plate, a block, a tilted disc with pins and a pointed spindle, a small ring and a toothed collar, and a thin rod.

- A (bench top, left of centre): label
- B (right end of the bench top): label
- c (screw block on the left post): label
- h (pulley wheel at the left end of the bench): label
- g (small upright block by the pulley): label
- f (turntable disc on the bench; also on the tilted pinned disc on the floor): label
- e [?] (block on the bench beside the turntable — e or c, not settled; also on the block on the floor): label
- o [?] (spindle collar under the turntable; also on the hollow cylinder on the floor — each a letter-sized ring, which may be the letter o or a drawn axle hole): label
- b (tall upright block on the right half of the bench): label

- d (screw block on that upright): label
- n (left front post): label
- m (right front post): label
- F (notched board between the posts): label
- L (short upright holding the treadle bar on the floor): label
- r (block holding the hemisphere): label
- s (first grinding plate; a smaller mark by the second plate's rim may be another *s* [?]): label
- p (toothed ring on the floor): label
- i (slotted plate on the floor): label
- t (thin rod at the bottom): label
- A [?] (second capital-like mark on the bench top, right of centre): label
- a [?] (small letter on the left front post below *n*; may be *c*): label
- x [?] (small mark on the right inner post by the bench end): label
- q (small letter on the hollow cylinder below its *o*): label
- [?] (small letter on the small ring at far right of the floor): label

Blank page (the back of the plate opposite; the engraving shows through in mirror image).

skilful method, can be worked and polished. The motion on this bench is perpetually continuous, direct and circular, driven round in a circle; and it never runs backward, as usually happens with others, even though it is only trodden and governed by the feet. Moreover, not just one dish and plate, or one ball, but as many as one likes can be fitted to this turning-bench without great effort and labour, as is set out abundantly enough, in ways [modis], in the following diagram and its description.

Let the bench as drawn be five feet long, or thereabouts. The stays of the bench, a x, and also b, must be strong enough for the bench A to be held all the firmer by them. Next, an oblong hole B is to be cut in the bench, so that the block b, and the knee e, which the socket [matrix] i surrounds, can be moved and wedged. The spindle in the socket i is driven round in a circle; the disc f is firmly attached to it, fitted with four iron pins, by means of which all the dishes and balls can be set on the disc and held immovable. The dishes, however, which s marks here, must first be set on special wooden discs, in which four holes are seen bored on the underside, matching the four pins, so that the dishes can be conveniently set on them and taken off again. Similarly, a hollowed block of square shape, r, surrounds the middle part of the balls; it too is pierced with four holes on its underside. This spindle, together with the disc and the dish or ball set on it, is drawn by a driving cord, which is first tied tightly to the upper long round pole, and is then passed through the pulley g, fixed on the bench A, and through the pulley h, attached to the stay a and tied lower down as well to the sill L. With this instrument and mechanism, when the foot is moved, the spindle turns in its socket, pointing upward, as appears from the figure.

To keep the disc from running backward, however, a collar or band must surround the spindle, made up of two separate parts, which o and p represent. The first part of the band, o, should be so made that it can be fitted to the spindle, with a steel rod q fixed to it; then the second part, p, must also be fitted suitably to the band o, and be secured by a small toothed iron wheel. By means of this band and wheel, as well as the rod (if these parts fit together properly and are joined by a pin),

running back is prevented whenever this part is driven backward. And so this mechanism always turns with a direct motion, and becomes so easy to turn that one cannot notice whether the motion is impeded or runs backward.

The two blocks d and e, which enter a and b, sit loosely in them, so that they can either be pushed in deeper or moved further out toward the front. The board F is laid on these blocks so that the arm may rest on it, and the lenses clinging tightly to it may be held more firmly, so that they can thus be turned in the dish with a contrary motion. This board can be fastened with wooden pins to the parts c and d already mentioned, which in turn should be held tightly on the outside to the stays a and b by wooden blocks [trochleae], so that nothing wobbles or moves even slightly. Moreover, these two smaller stays of the turning mechanism, n and m, are pierced for two wooden pins, by which a bench can be set against them, should one wish to sit at it. Let this much be said briefly about fitting out this turning mechanism; whatever seems not to be explained sufficiently here can be understood more fully from the accompanying diagram.

As for the actual craft of polishing the glasses, the first thing to examine, before everything else, is whether the dishes, plates and balls come close to an exactly round figure and consist of a precise segment of a sphere. For otherwise, if they stray from this exact standard of perfection and do not attain complete roundness, the glasses acquire an uneven surface, are in danger of being damaged by knocking, and, glinting unevenly, are of no use. But if the dishes are exactly round, the work of polishing goes all the more easily, especially when the lenses are of some size. [Margin: Lenses and balls must be of an exactly round figure.]

And I think the glasses can be finished by a not dissimilar method if the plates are covered with cloth, and care is taken that the glasses are not scratched during the very rapid motion.

Furthermore, this turning mechanism can also be applied to turning other materials (for example, wood, ivory, brass, etc.) into a round or angular shape, if a special socket [matrix] is fitted to the stay b of the bench, and a sharp pin opposite it, at a. [Margin: The mechanism described above also serves for other things.] And if you also want the lathe to be turned in the common way, then take the spindle without the band, or, if in a circle

it is to be driven continuously, then use once more the band and belt mentioned earlier, with the rod and the wheel; in this way angular shapes too can be formed more conveniently.

As for the method of testing the quality of the lenses used in tubes, three things must be considered here. [Margin: Which lenses are to be chosen for telescopes.] First, the lens itself must be examined: how it has been hollowed, worked and polished. It must be free of bubbles, grains of sand and swirls. Glass of this kind, suited to this purpose, is in fact made nowhere better than at Venice.

Second, the glass must not be blackish, dusky, yellow or green, but thoroughly clear, white and free of any foreign colour. Glass that is faintly blue, however, is highly recommended for making dioptric lenses from it, and is often better than glass that is too white. It is also always more suitable for making telescopes than natural rock crystal [Crystallus montana]. For although rock crystal is very transparent and brilliant, it produces a greater refraction than other glass — something that a person without experience will perhaps scarcely believe. [Margin: Rock crystal is subject to greater refraction than glass, especially glass melted at Venice, and is therefore also less suitable for making telescopes.]

Third, whether a lens has been neatly polished and worked can be recognized only with difficulty by the unpractised, who have not tried their hand at this craft. Nevertheless, so that anyone may be able to tell good lenses from faulty ones, I shall add some marks against which their quality can be measured. [Margin: How lenses of good and perfect section are to be distinguished from faulty ones.]

I. Lenses are good when they appear correctly hollowed — that is, when no small holes, little cavities or light scratches are found in convex and concave lenses (such as can be pressed into them by the sand with which they are hollowed), but when they are seen to be worked evenly all over.

II. It is also a sign of quality when a convex lens is equally thick all round its edge. For if it is of unequal thickness around its circumference, this shows that the centres on the two sides do not correspond to each other παραλλήλως [Greek: παραλλήλως (parallēlōs, "in parallel")]. For this reason such a lens is of no value in a tube and can achieve nothing in dioptrics.

III. With your lens applied, look at some body that is round, or square, or of some other figure, and observe carefully whether or not it keeps its proper figure. For

if this object is seen in an oblong shape, or in some other, different figure, the glass is not round enough, nor properly hollowed and worked.

IV. One must also see whether the lens glints unevenly or is in good order. This is so when objects set in a straight line and falling on the lens, or upright bodies, appear in the lenses not in the least curved, oblique or raised. This can be detected if the lens is turned towards windows, and the windows, glinting in it with their strips of lead, present themselves to the eye in a straight line and in their true position, and do not appear curved or arched towards the circumference of the lens. For if all the parts of the window are shown exactly

in a straight position, it is a sign that the lens has been correctly hollowed and worked to the proper section, in the middle as well as around the edge.

In this way you can also tell from what segment a convex lens is formed, whether a larger or a smaller one. [Margin: How the different figure of lenses may be recognized.] For in a lens that takes in a larger segment of the sphere, the little window-panes appear larger than in another that takes in a smaller one. And the smaller the little panes seen in the lens, the smaller the tube it requires. The same judgement holds for concave lenses: the smaller the diamond panes of the window [Rhombi specularii] appear in them, the deeper they are, and so the smaller the spherical segment they are formed from.

Third, with regard to the polishing of lenses, one must further attend to the following. [Margin: The mark of perfect polishing.] 1. Whether all the light scratches have also been removed by thorough polishing. 2. Whether the lens still shows any mists, like little clouds, which make the lenses look as though covered with a thin skin; for lenses in which these are seen are not yet sufficiently polished.

Nor should it go unremarked here that a lens can be polished beyond due measure. This shows itself when a lens glints unevenly because it has not been polished correctly, so that the proper section of its figure has been altered and too much has been removed from the lens in polishing, in the middle or at the edge. This can easily happen if the cloth of the plate on which the polishing is done does not exactly fit the segment of the glass. [Margin: A particular cloth (*telum*) that serves for polishing is to be applied to each plate or segment of glass.] Whoever wants to avoid this fault must apply its own particular cloths and polishing instruments to each spherical segment. More indeed on the method of

polishing glasses, and on the other matters briefly mentioned in this chapter, I could have brought before the public, had the plan of my undertaking allowed it. But since I decided not to treat such things expressly in these prolegomena to the *Selenography*, these few remarks must suffice.

CAPUT II.

Chapter II.

On the variety, differences, construction and use of optical tubes, and how good ones are to be distinguished from faulty ones.

That by means of the recently invented optical tube (a truly ingenious invention, and one that can never be praised enough as it deserves) any small bodies whatever, scarcely perceptible to the sense of the eyes — indeed, near and distant objects alike — appear and are shown large, clear and distinct to younger and older people alike (unless they suffer from thoroughly impaired and blinded sight), is no longer unknown to anyone. [Margin: Optical tubes serve every healthy eye.] But what the cause is that the eye can be armed more by one tube than by another, so as to grasp the objects more clearly by sight,

I shall pursue at some length in this chapter. [Margin: One tube reveals an object to the eye more clearly than another.]

First, however, it must be understood that tubes made from a spherical section have, above all, a fourfold difference, and four kinds. [Margin: The four kinds of tubes.]

1. The first kind is called the Telioscopium or Telescopium [telescope]. 2. The second is called the Helioscopium [helioscope]. 3. The third, the Microscopium [microscope]. 4. The fourth, the Polemoscopium [polemoscope].

As for the first kind of dioptra, called the telescope, by this name is understood an optical tube of the kind that is applied to the eyes not only for the accurate inspection of terrestrial bodies — as most people commonly use it — but also for the inspection of celestial bodies and for observations of the stars. [Margin: On the construction of the telescope.] Just as this kind of tube is made in a definite fourfold way, from which almost countless others then arise, so I have set out this kind first, in order and one by one,

before I make any mention of the remaining three.

First, then: a telescope of this kind is commonly built from two glasses, one convex and one concave. The concave is placed nearest the eye, while the convex, as is well known, is turned towards the visible object. A great difference is found between the two glasses, considered both absolutely and in relation to each other, as regards their effects in sharpening the eye's vision and enlarging the size of visible things; more on this will follow later.

Telescopes of this kind can, moreover, be made in different ways according to their different lengths.

1. For telescopes which, drawn out of their tubes for use, are one foot long, one glass must consist of a spherical segment convex on both sides, whose diameter is four Danzig feet, and the other of a glass concave on both sides, polished on a ball whose diameter equals four and a half digits [digitos]. [Margin: Construction of telescopes one foot long.] This Danzig foot, expressed in the smallest parts, stands to the Rhineland fortification foot in the ratio of 914 to 1000, and to the royal Paris foot in the ratio of 914 to 1055. [Margin: The ratio of the Danzig foot to the Rhineland fortification foot and the royal Paris foot.]
2. If, however, the length of the tube is to equal one ell, then a glass convex on both sides should be prepared from a single segment whose diameter is about five feet; and the ball fitted to the concave must not exceed 5½ digits. [Margin: Structure of a tube one ell long.]
3. But if a glass convex on each side has been prepared from some segment whose diameter is eight feet, and the previous concave is kept, it then yields an optical tube 3½ feet long. [Margin: Composition of a tube of 3½ feet.]

4. Further, if you fit to a concave of this kind a glass convex on both sides whose segment has a diameter of ten feet, you will obtain a telescope more than two ells long. [Margin: A tube of two ells and more.]
5. In addition, a glass convex on both sides and polished in a dish whose diameter equals twelve feet yields an excellent optical tube five feet long and more. [Margin: A tube of five feet.]

From this it is easily understood that the longer and more extended a tube is, the larger and more obtuse the segment of glass it requires. [Margin: The longer the tube, the larger the segment of the convex.]

It is also worth noting that a convex glass that is plane on one side makes a tube twice as long as it would if the glass were convex on both sides, and that a dioptra of this kind represents the images of objects much larger and more distinctly, and enlarges the angle of vision. [Margin: A glass convex on one side only renders the images of things twice as large as one convex on both sides.]

The opposite happens with concave glasses: those polished and hollowed on one side require smaller optical tubes, whereas those hollowed out on both sides require larger ones. [Margin: Glasses hollow on one side call for smaller tubes; those hollow on both sides, for larger ones.]

In the same way, glasses worked on a smaller sphere claim longer tubes, and those worked on a larger sphere shorter ones; and always the longer, the smaller the sphere is. [Margin: Glasses worked on a smaller sphere require larger tubes; on a larger sphere, smaller ones.]

Another rule, common to convex and concave glasses alike, should also be noted here. If a glass concave on one side is applied to a glass convex on both sides or on one side, visible bodies do appear clearer than if a glass concave on both sides is used; but, conversely, they are not seen at so great a size as through a glass concave on both sides. [Margin: A rule common to convex and concave glasses.]

Again, a glass concave on both sides made on a smaller sphere renders objects larger than one polished on a larger sphere, and indeed in proportion to the balls. Hence concave glasses polished on a smaller sphere, and convex glasses polished in a less elevated dish, supply longer optical instruments and render and display objects nearer and larger. [Margin: The property of glasses concave on both sides, worked on a smaller and on a larger sphere.]

Here, however, it must be noted that the sharper the hollow lens you use — that is, the smaller its sphere — the more dimly visible objects appear. A middle way must therefore be taken here, and some middle proportion between these lenses chosen, which use and daily experience will teach everyone. [Margin: Glasses hollowed too deeply depict the images of things more dimly.]

But so that you may arrive at the right proportion of the two lenses for fitting out a good and sufficiently long optical tube, know that you first need a glass concave on both sides, worked on a sphere of 5½ digits, and also a glass convex on both sides, prepared from a segment whose diameter equals twelve

feet (as was also said above). In this way you will obtain an excellent tube, five or five and a half feet long, and thoroughly suited to observations of the stars — which, however, is said on the condition [Margin: Construction of an excellent optical tube.]

that you are to understand it so: the lenses must be good, not coloured, and properly polished and smoothed, since it will present objects sufficiently large, clear and distinct. But if you want a still better tube, to widen the angle of vision all the more, let the convex lens, in the proportion just stated, be plane on one side, while the other lens remains concave on both sides. In this way you will obtain a sufficiently long and excellent tube of about eleven feet, which will without doubt satisfy you, provided that both lenses have been perfectly worked. [Margin: An optical tube of eleven feet, or about that.]

This point, however, must be carefully impressed: in building a tube of this kind, a glass concave on both sides is preferable to a concave-plane one, because the latter does not make the images of visible things appear as large as the former does, and moreover often falls short of perfection. For it takes greater skill to make and polish a glass surface exactly flat than to make it hollow, as all who possess this knowledge and have carefully worked such glasses are compelled to admit, taught by experiment. This is indeed flatly contrary to Father C. Scheiner, as can be seen in Book 2 of the *Rosa Ursina*, chapter 33, folio 135, where he discusses practical doubts. [Margin: A lens concave on both sides is more convenient than a concave-plane one.]

Further: that a convex lens prepared from a more obtuse segment of a sphere and fitted to an optical tube has greater power in representing the images [ſpeciebus] of visible things than one made from a sharper and more globular segment — even though, used on its own in place of a spectacle lens, the latter shows the eyes larger images of things and the former smaller ones; that, similarly, a sharper concave lens enlarges visible images more than a more obtuse one, although outside the tube the former shows everything smaller; and that a smaller and shorter tube is of lesser power and more subject to refractions — for all this I prefer, for now, to call as witness constant and plain experience rather than a demonstration drawn from the doctrine of refractions, to which this inquiry properly belongs. [Margin: A convex lens from a more obtuse segment gives a better and longer tube than one from a sharper spherical segment.]

If, however, lovers of mathematics delight in examining the demonstrations themselves, they can find them in the writings that certain most distinguished mathematicians have published at length on this subject. From their number it will be enough merely to cite Kepler's *Dioptrice*, the *Rosa Ursina* and the *Oculus* of Father C. Scheiner, the treatise of Antonio de Dominis [Marco Antonio de Dominis] *De radiis visus et lucis*, and also Mau- [Margin: The authors in whom a demonstration of tubes is to be found.]

rolycus [Francesco Maurolico]. For it is not my intention to deal here expressly with what concerns the making of lenses and optical tubes; I am

reserving that subject for a separate treatise. So much, then, for the first kind of tube (namely telescopes), which consists of two lenses, one concave and one convex.

The second kind of telescope is made of two convex lenses. The lens to be placed at the eyes is commonly taken from a small segment, since a large segment would require too long a tube; and so the lenses too must be worked to suit the length of the tube, longer or shorter. The difference between this telescope and the earlier one is that the former presents all objects upright and in their true position, while this one presents everything inverted. For that reason it serves above all for observing the stars, and especially the spots of the Sun. For just as the first kind shows inverted the images of visible things that are projected onto a board and represented on it, so this second kind conveniently shows the spots of the Sun in an upright position, as they are found in the sky according to their quarters. [Margin: Telescopes also consist of two convex lenses.] [Margin: Two convex lenses properly arranged in a tube invert everything.]

The third kind is made of three different glasses, namely two convex and one concave. It is necessary, however, that the upper convex lens be somewhat flatter in such a form, if the effect is to answer to the workmanship; the concave lens is kept nearest the eye. Between these two is placed the other convex lens, worked from a segment of a smaller sphere. The proper position of this lens in the tube, and its proportion to the other two, practice itself will teach you. [Margin: A telescope made of two convex lenses and one concave.]

The fourth kind of telescope can be constructed from three convex lenses, if each is set in the tube in its proper order and according to its proportion. If the glasses have been brought to perfection, it presents objects to be viewed in an upright, fine, distinct and clear position (as the first and third kinds of telescope also do). [Margin: A telescope fitted with three convex lenses.]

Before I go on to the remaining kinds, however, I shall also briefly say something about the material of telescopes, from which their tubes and draw-tubes [ductus] are made. The draw-tubes of the larger telescopes [Margin: Why paper tubes seem not very convenient.]

are mostly made up of paper, as tubes of this kind are used by Iohannes Wiselius [Johann Wiesel], optician of Augsburg, who has devoted the greatest care to fitting them out, and also by Vangelista Torrezelli [Evangelista Torricelli], Mathematician to the Grand Duke of Tuscany. Paper tubes, however, do not appeal to me, for certain reasons which I shall now give. First, if their draw-tubes are made very tight, they become tighter in damp weather, and so can be drawn out and pushed in only with difficulty; if, on the other hand, they are loose enough, they become looser in drier weather, and so are easily shifted from their proper seat — and always having to put the tube back into its seat is a great nuisance. Second, they are not durable but are quite easily spoiled, especially if they take up any moisture from outside. Moreover, while they are being drawn out and pushed in, the lenses are easily sprinkled and

stained by floating specks of dust, so that they become dimmer. Finally, and worst of all, in a longer paper tube of this kind the upper and lower lens seldom stand at an equal distance from each other, especially if the tube consists of several draw-tubes. For as the draw-tubes are extended, the straight alignment of the lenses is disturbed, and because of this error the images of visible things are poorly represented. All the lenses in telescopes must necessarily be exactly parallel if the images of things are to appear not confused but distinct and large. The draw-tubes must therefore always hold together exactly in the same parallel line.

If the tubes are made of thin iron plates (which can indeed also be done), another difficulty arises: if a telescope is assembled from several pipes of iron plate, its weight makes it barely manageable. For this reason tubes carefully fashioned and turned from the best dry wood, and not put together from many parts and draw-tubes — so that the parallel line of the lenses is not disturbed — have always seemed to me the most convenient of all, and have served me as I wished. So when the length of the telescope equals 12 feet, I have its front portion made about 8 feet long. And since it is impossible for the tubes [dioptras] to be made from a single piece of wood, I have them built from separate parts, very carefully arranged along a straight line and tightly glued together. The remaining piece [Margin: What is lacking in large tubes made of iron plates.] [Margin: Tubes made of solid, dry wood are approved, and their construction is described [?].]

provides two or three draw-tubes, so that the optical tube can be properly extended along the parallel line of the lenses.

As for the two apertures [foramina] of the tubes, which are found in each tube and are set between the two lenses, it should be understood that it makes little difference whether the rear aperture — the one near the eye, resting on the concave glass — is a little wider or narrower, provided it is large enough to give the eye an easy and free passage from one lens to the other. But the aperture of the tube nearest the convex glass must have its due and exact proportion: for if that aperture is wider than is right, the images of visible things do not appear clear or distinct enough; and if, on the other hand, it is too small, it again impedes vision. Here use and experience have taught me that the aperture of large telescopes next to the convex lens should not exceed 1½ inches in diameter. Although this quantity may seem very small to some, practice will teach anyone that this proportion of the aperture suits a larger tube best of all. [Margin: How the apertures of the tubes should be arranged.]

When, therefore, telescopes of the four kinds have been made according to the proportion and method just described (for on this occasion I refrain from reviewing further methods, though I could), and we should like to know which telescope is the most perfect of all, the one with which we can see objects most accurately, then above all these four points must be considered:

1. Which is the clearest and purest?
2. Which presents the images of things larger than the rest?

3. Which colours objects less, and 4. gives the least refraction of all? [Margin: The marks of the most perfect telescope.]

As regards the first two marks of the quality of tubes, I do admit that if someone is equipped with two telescopes and puts them to the test by viewing the images of external things with them more carefully, he can easily tell which of the two is to be preferred: namely, the one that represents visible objects more clearly and distinctly. Yet this test is not yet so sufficient that it is not liable to some error. For it is almost impossible to determine in this way how much it is that one or the other telescope

excels in clarity and magnitude, and also what the exact difference in distinctness is? For the sight is better disposed to see sharply at one time than at another, and the quality of the air can either hinder or promote this as well. Add that telescopes appear far better if, facing towards the Sun, they are applied to a visible external object than if they face away from the Sun; and that all things are seen larger when viewed through certain exhalations than without them — to say nothing of other causes that may stand in the way of testing tubes carefully. I shall therefore disclose a better method, and an infallible one, by which the quality of telescopes can be explored and their worth determined most accurately.

[Margin: An infallible method of exploring the worth and quality of optical tubes.]

Go into a darkened room with one telescope, bring it up to the hole in the window, and turn it to the Sun in the way sunspots are usually observed. Opposite the tube, set up a white board on which an observation circle has been drawn, of the size of the Sun's image. Then make the Sun glide through the tube onto the observation circle of the board. If the Sun's disc is larger than the circle, move the board closer to the tube until the Sun exactly fills the circle with its circumference. Then attend carefully to the brightness of the Sun, the colour of its limb, and its spots, if there are any on the Sun. This done, set the other telescope in the hole of the window as well, at the same distance, and again admit the Sun's light to the white board. You will then easily see whether the Sun's disc is larger than the circle drawn, whether the Sun's spots are larger than before, and whether everything appears more distinct or darker. If, then, you note the difference in both size and distinctness, you will easily judge from it the worth of the tubes, especially if the draws [ductus] are correctly set. The first two marks can be governed by this rule.

The third mark — whether or not the lenses colour things — will be explored in the following way. Turn the optical tubes on the stars: Jupiter, Saturn, or the fixed stars. If a tube shows these visible heavenly bodies pure, bright, free of blue, yellow or red colour, and round, not oblong — above all Jupiter (for Saturn is seldom seen round) — then the lenses are of good quality, in their

segment, perfect and well polished. But if the surface of the segment in the lenses [specillis] is uneven, misshapen and faulty, the rays are refracted beyond measure and colours are introduced. Some refraction must indeed be granted

in lenses, and because of it the images of visible things are either enlarged or diminished; yet the smaller the refraction of a lens, the more it tends towards evenness, and it brings in no foreign colours.

4. So that this matter may be understood all the better, I shall supply certain rules by which it can be examined. But since this doctrine is somewhat intricate, and it is not plain to everyone what refractions of rays are, how many kinds there are, and also where they arise, I shall first set out and propose certain principles and precepts about them, following the view of almost all writers on optics; from these the things mentioned earlier will be grasped more correctly and understood more fully.

[Margin: Certain rules, five in number, on the nature, the differences and the production of the refraction of rays.]

I. That every visible point projects rays from itself spherically, and indeed perpendicularly into the eyes, through some transparent medium [diaphanum], which may be either rarer or denser. Anton. de Dominis [Marco Antonio de Dominis], ch. 4, *De luce et umbra*, p. 10.

[Margin: First rule.]

II. That every ray falling on a transparent medium perpendicularly and at right angles proceeds straight on and is not broken, but continues and passes through unrefracted, and is therefore called direct; and that all other rays, which fall not perpendicularly but at oblique angles, are broken at the points of incidence and inclination. Witelo, book 2, theorems 42 to 48; Maurolycus [Francesco Maurolico], book 1, *De lumine et umbra*, p. 36. They are broken towards the perpendicular when rays coming from a first, rarer medium fall into a second, denser one; conversely, they are broken away from the perpendicular when these rays pass from a denser transparent medium and strike a rarer one. The perpendicular towards which, or away from which, refraction takes place is the line that stands at right angles on the surface of the second medium, or transparent body, at the point of incidence. Kepler, *Dioptrice*, axiom 2; Scheiner, *Rosa Ursina*, book 4, part 1, ch. 23, p. 452, and in the same author's *Oculus*, book 2, part 1, ch. 3, p. 59; Aguilonius [François d'Aguilon], *Optics*, book 2, proposition 8, p. 120. And this is the reason why rays falling on dense, polished glass are refracted — not so much because of its density and thickness, which is commonly slight,

[Margin: Second rule.]

than because of the convex and concave figure of the glass, which certain spherical and conic segments supply. This figure brings it about that the more the incidence of the rays inclines to oblique angles and deflects from the centre, the greater the refraction it produces; and the smaller the angle of incidence, the smaller the refraction becomes. For the angles of incidence and of inclination are proportional to the angles of refraction. Witelo, *Optics*, book 2, theorem 50, and book 10, theorem 14; Maurolycus, book on transparent bodies, theorem 10.

III. The refraction of rays is also greater in convex lenses made of segments of smaller spheres (because they rise more in the middle and are thinned more

at the edge) than in those made of sections of larger spheres — namely, because of the greater obliquity of the angle of incidence; and in convex lenses of every kind it is towards the perpendicular. Hence the angle of vision is widened, and the images of visible things appear larger, by virtue of hypotheses 5 and 6 of Euclid's *Optics*, and Witelo 20, book 4, as also Maurolycus, book 1, *Diaphana*, proposition 4, p. 36. Things seen under a greater angle are seen as larger and nearer, and things seen under a smaller one as smaller and more remote.

[Margin: Third rule.]

IV. Likewise, the refraction of rays is greater (but away from the perpendicular) in concave lenses made of segments of smaller spheres than in those made of segments of larger spheres; hence these form a smaller angle of vision, and those a larger one.

[Margin: Fourth rule.]

V. The nearer the perpendicular rays are to the centre of the lens, the more directly they fall, the more strongly they penetrate, the less they are refracted, and the more clearly they represent the images of visible things. But the farther they are from the centre of the lens, and the more they tend towards the periphery, the more obliquely and weakly they strike the surface of incidence, or of the transparent medium, and so the more they are refracted and the less distinctly they present objects to be seen — by virtue of proposition 47 of Witelo's *Optics*, book 2, I.

[Margin: Fifth rule.]

From this it follows, first, that everything convex in which the rays are refracted towards the perpendicular widens the bases of the angles that form the images, and enlarges the images of visible things; and conversely, that everything concave in which refraction takes place away from the perpendicular contracts the bases of the angles that carry the images, and therefore presents the images of visible things smaller. Second, it follows from the same that rays in lenses, whether convex,

[Margin: Which lenses present the images of things more, and which less?]

or concave, are refracted more near the edge than near the centre; that for this reason they widen the angle of vision more there; and that consequently the images of visible things appear larger near the periphery than near the centre. This indeed happens in all lenses [specillis] made of spherical segments, yet more evidently in one than in another, according as the segments are larger or smaller. And so all tubes that induce less refraction are to be judged better and more valuable, and above all more suitable for observing the stars. How this is to be investigated I shall now also show in a few words.

And although the inequality of refraction in tubes can be detected in many ways — chiefly by means of the spots of the Sun, as Christoph Scheiner explains at length in the *Rosa Ursina*, book 4, part 1 — yet among those ways the four that follow hold not the least place. But I would have you note here that anyone who wishes to work profitably in this matter must know the method

of observing the spots of the Sun; and if someone lacks that knowledge, let him consult the following chapters, in which this subject will be treated.

[Margin: By what signs the inequality of refraction in tubes is to be recognized.]

I. Take some particular spot that clings to any part of the Sun's disc, whether the eastern or the western, and admit both it and the image of the Sun through the tube. Make the spot of the Sun fall on the eastern horizon of the observation circle, and mark its centre in its place. Then, with the tube and the observing instrument kept unmoved, allow the Sun and the spot their free daily course, and at distinct intervals, until the spot has passed through the centre to the periphery of the western part of the observation circle, again carefully mark the centre of the spot on the paper. There is time enough for this, since the Sun takes about 2^{m} of time for its transit — that is, near its apogee. This progress of the Sun is either rectilinear or curvilinear. For if it passes through the centre of the observation circle, that motion takes place along a straight line; but if it proceeds somewhat farther from the centre, towards one side of the circle or the other, it takes place along a bent and curved line, and the convex face of the curvature will always incline towards the centre, while the concave face, turned away from it, will be turned towards the points of the zenith or the nadir. Thus from the progress along a straight line,

[Margin: First method of exploring the qualities and differences of tubes in refracting.]

no refraction is inferred, but from progress along a curved one. For the greater the bend of the curvature appears at an equal distance from the centre of the observation circle, the greater is the refraction of that tube. By this examination of the greater and lesser curvature and refraction towards the periphery on either side, which is detected by careful noting of the points, the difference between lenses and between tubes is recognized, and also their good or bad figure.

II. Likewise, if the spot appears near the rising or the setting horizon, first the place of the spot is marked on the observation circle; then a straight line is drawn through this point and through the centre of the circle just mentioned, and the distance of the spot from the periphery and from the centre is brought to exact measurement. The discrepancy between the two shows the difference sought, which will always be greater at the edge, on either side, than in the middle. Therefore, according as the lenses of the tubes exceed or fall short more or less in refracting near the edges and near the centre, so much the poorer or the better are the tubes to be judged.

[Margin: Second method, for the difference of refractions.]

III. Further, if two spots occur somewhat apart along the length of the Sun's diameter, note the interval between them both near the horizon and in the middle, since from this too you will perceive the difference of refractions: that interval will always be observed to be narrower in the middle (as was also said before) than at the edges.

[Margin: Third method of investigating the difference between tubes in refracting.]

IV. Moreover, some larger spot of the Sun will disclose the force and nature of lenses that refract unequally, if its own length along the diameter is observed exactly both near the horizon and near the middle. For from this mark too the difference of refraction will become known, and which tube is the best and the most suitable for observations of the heavenly bodies. And let this suffice concerning the first kind of optical tubes, namely telescopes.

[Margin: Fourth method of exploring the inequality of refraction.]

Second, as regards the helioscope, which Scheiner mentions in book 2 of the *Rosa Ursina*, fols. 128, 130 and 132, and whose use in observing the spots of the Sun he shows: it must be understood of this instrument that it is directed straight at the Sun, to look at it without injury to the eye — which cannot be done with a telescope. Hence, with the help of the helioscope,

[Margin: The use and construction of the helioscope.]

not only the spots but also the eclipses of the Sun can conveniently be observed. The helioscope is constructed in two ways. In the first way, following Scheiner's idea, both the concave and the convex lenses of helioscopes can be made from glass of different colours — red, blue, yellow, green — provided, however, that the glass is sufficiently transparent and evenly coloured, although these two good qualities of glass seldom occur together. The helioscope admits either one convex lens, or a concave and a convex, or two convex lenses, or finally several, after the fashion of telescopes, provided the lenses are skilfully made and correctly fitted in the tube.

The second way readily commends itself, as I have learned from my own practice and experience at home; for in this way any telescope can be changed into a helioscope at any time, whenever there is need. Take two flat glasses, coloured in any way you like and shaped to the size of the telescope's concave lenses. Between the two place a paper of the same size, pierced with one small hole, and join it firmly to the glasses, either with thread or, better, with a special glue (the one with which craftsmen join glasses that are to be polished to a wooden tool). Afterwards apply these glasses, glued together with the paper, to the concave lens of the telescope, the one next to the eye. In this way you will have a helioscope ready that is suited to viewing the spots and the eclipses of the Sun, and the telescope itself remains undamaged whenever these coloured glasses are taken out.

[Margin: To make a helioscope from any telescope.]

The third kind of tube is the microscope, which is also commonly called the fly-glass [vitrum muscarium]. It makes the tiniest particles and little animals (which by themselves scarcely meet the keenness of the eyes) visible at almost the size of camels and elephants, so that they are viewed not without great wonder and pleasant delight. It consists of two glasses and a little tube of 1 inch, or thereabouts, into which the particles are put. One glass, the one nearest the eyes, is convex, polished from a small segment of a sphere whose diameter

equals at most 2 inches. The other, lower down and near the bottom, on which the things to be examined are placed, is only a simple small piece of glass, flat on both sides, whose action consists solely in this: that

[Margin: The structure and use of the microscope.]

it lets in the light.

[Margin: Another way of preparing a microscope.]

Alternatively, a microscope of this kind can also be built from two convex glasses and put into the form of a little tube; for in this way too, very minute objects placed in it, which escape the sense of the eyes, will appear clearer and more distinct than in the first microscope. The one convex glass, which is directed towards the things to be viewed, must be raised [elatum] and worked from a small segment of a sphere; the other, which is brought up to the eye, is to be shaped somewhat flatter. Here too the due proportion of the lenses and of the draw-tubes of the tube must be carefully considered, according to the quality and figure of the glasses [specilla], if the smaller parts of a tiny body are to be depicted in the eye as sharply as possible.

[Margin: The polemoscope, invented by the author.]

Next I turn to the fourth kind of tube, which I call the polemoscope [Polemoscopium], because it can be used most conveniently in time of war, both by besiegers and by the besieged. I myself devised and built this optical instrument in the year 1637, and I do not believe (I would wish this said without boasting) that it had ever been seen before that time, or put together by anyone. And although I have learned from others that there is someone here who claims the invention of this polemoscope for himself, yet if he goes on talking in this way, he will stand convicted of idle talk on his own testimony. For he himself is not unaware that he saw this optical instrument at my house not once but several times, and examined it from every side, because its design and construction greatly pleased him. As for this fine fellow's wishing to reproduce that instrument by a half-finished imitation (for this affected polemoscope of his will never achieve what mine does, since it is composed of catoptric glasses only, and not of dioptric ones as well), it seems to have been contrived with the same kind of cleverness as that by which the Spaniards, taught by Columbus the Genoese, had stood an egg upright by crushing its end at the point; before they had seen it done, this was as plain to them as the thing they knew least of all — as is related in Calveton's [Urbain Chauveton] *History of the New World* [Historia novi orbis], page 23. For I readily grant that its construction, once all its parts have been inspected, is not very laborious, nor is its invention of such great moment, since it is composed of parts known to craftsmen. But it is on this very account above all that

our polemoscope [Pelemoſcopium] commends itself not a little: that, built by an easily procured method, it can achieve what you would expect in vain from other instruments made with far greater labour and expense.

[Margin: By no means is that thing the most excellent whose use depends on great difficulties.]

[Margin: The uses of the polemoscope.]

This optical instrument, moreover, is not only full of pleasant contemplation and delight, but also exceedingly useful and necessary. For, first, it can present any visible object face down, face up, tilted towards its front or its back, upright or inverted. Next, equipped with this instrument, I can perceive by sight any visible things around a right angle, that is, by rays at right angles, reflected as well as refracted — something denied to the other tubes, since they present every visible thing to the sense of the eyes by straight and refracted rays. But by means of this instrument I can view something that another person without it cannot perceive by sight, and I can see anyone who in turn cannot see me. Thus, looking out from a room, I can bring into my view, very clearly and distinctly, everything that is going on outside, whether in a nearer or a more remote place (which another person cannot look at through a lattice, or indeed by himself, because of the awkwardness of the spot), turned to every aspect — upright, inverted and sideways — under as large an angle of vision as even the best telescope can form. Besides, this optical instrument is used no less usefully for seeing when I stand at a wall, at gabions [corbes loricales], at a hedge or other cover of that kind: there, brought up to the upper part, it presents the things outside to the gaze, so that the observer cannot be seen by anyone outside. Finally, its most useful and most conspicuous use of all is when, in time of siege, leaning on the firing step of the rampart, I can accurately observe with this instrument, above and beyond the parapet, everything the enemy is doing in the ditch — especially once the mantlets [vineae] have already been brought into the ditch. For there none of the besieged dares to look into the ditch in the ordinary way, with his face raised above the rampart, without great danger to his life, because of the presence of enemy soldiers intent on everything that goes on up on the rampart. I shall deal with this at greater length later, once its construction has first been explained.

[Margin: Construction of the polemoscope.]

This tube, then, is prepared on both catoptric and dioptric principles: for it consists of two plane mirrors and a pair of dioptric glasses, namely a concave and a convex.

The outward shape of the tube is as shown in A; at g it forms a right angle. Its material is cast from yellow copper [aes flavum], that is, brass, which is more suitable than white sheet iron. It has five distinct parts, namely a, d, c, g, e, made to fit together so that the glasses can be conveniently put in and taken out whenever necessary. The first part has on its upper surface a round little box, screwed in, in which there is a round hole, about a third of an inch across and open right through. A concave lens is afterwards enclosed in this little box and secured with iron wire. Lower down, towards a, opposite the hole, is placed a piece h of a clear, good plane mirror, prepared from an elliptical segment, of such a size that it can be conveniently set in place and inclined at about 45°, as the line a placed beside it shows. But so that it may be fixed the better and more securely, first set beneath it a little piece of copper bent like i; and so that

the foil [folium] is not disturbed, glue on a paper smeared with wax, then run wax round the edge, so that the glass cannot be moved from its place or fall out. Next, the first part a, together with the little box b in which the concave lens is placed, is joined by four screws to the part d, which is inserted into the pipe C, so that the tube can be extended at will when necessity demands.

Secondly, in the part of the instrument bent at a right angle, a plane mirror k of an elliptical segment is again set in, as the line at g shows. It matters a great deal that this be placed in the proper position: for if it leans towards either side, or is tipped up or down, then neither are the rays which fall at f, by the angle of incidence, onto the mirror g carried by the angle of reflection into that same a, nor do they reach the eye from a through the hole. Anyone, however, will learn from practice itself how much depends on the correct arrangement of this mirror. For that reason it should at first be set and held in its place with a little wax applied, until its proper position is fully established. Sometimes, too, the front one at a is not correctly placed; and so it comes about that the images [species] of visible things strike the eye not directly, as they should, but obliquely.

Diagram. A full-page engraved plate of the polemoscope described in the preceding text, captioned *Fig. B.* at the foot. At the top, the instrument assembled, marked **A**: a long horizontal tube with a vertical limb rising at the left through a right-angled elbow, and a small round box projecting from the right end. Below it, a second assembly in two pieces — the vertical limb with its elbow and the first section of tube on the left, and on the right, marked **B**, the second section with the box. Between them lie loose parts: an oval glass (no letter visible on the scan), rings and discs. In the third row the tube is taken fully apart into the pieces marked **E**, **D** and **C**. The lower half of the plate shows the parts enlarged: the elbow-piece cut at a right angle, the box section seen from the side and from the end, discs, open rings, a split ring, a tilted disc on a bent support, and two oval glasses.

- A (top centre): the assembled instrument; on it f (top of the vertical limb), e (vertical limb), g (elbow), c (horizontal tube), a and b (the box at the right end)
- second row, left assembly: f, e, g, c
- second row, loose parts: p (open ring), o (disc), n (split ring), r (open ring), q (disc with central hole), h (oval glass), i (tilted disc on a bent support)
- B (second row, right): the second section, lettered d, a, b
- E, D, C (third row): the separated pieces, lettered g, c, d, a, b
- lower group: m (thin disc, upper right), b, a, h (the box seen from above, with an open end), a, b (the box section seen from the side), g and w (the right-angled elbow-piece), o (disc), n (split ring), r (open ring), q (disc with hole), i (tilted disc on a bent support), v and t (rings), k and h (oval glasses)

• caption (foot): *Fig. B.*[2]

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Nevertheless, a diligent, careful and attentive practitioner of this study, once warned, will avoid those errors. The fourth glass, namely the convex one, is placed at s in the tube d, enclosed in the small ring n. This ring is shaped so that it can conveniently be put into the tube, and so that, by moving the ring this way and that, the proper place and position for this lens can at last be found.

But someone may perhaps ask me what proportion of convex lenses suits this purpose. My answer is that various lenses, whether flatter or more steeply curved, can indeed be used as one pleases, provided that one observes this difference, unless one wants to waste one's labour: the more steeply curved lenses also require a longer tube d, and so a longer polemoscope as a whole.

Two further precautions are also necessary for the maker of this polemoscope, unless he wants to go wrong. [Margin: The lenses in a polemoscope require a shorter distance than in a telescope.] The first is that the placing of the two lenses, concave and convex, requires a different separation here from that in other telescopes: for the distance in this instrument must clearly be shorter if it is to meet expectations. The second is that it is better here to use a plano-concave lens than one hollowed on both sides, because it presents objects more clearly and, as far as the purpose of the device requires, distinctly enough.

It will perhaps seem surprising to someone how each lens achieves its purpose, when the one does not stand exactly opposite the other, and a mirror is placed between them besides. But in fact neither of these hinders the use of this polemoscope, provided only that the glasses are set evenly in their tubes: for just as the rays refracted by the convex lens fall onto the mirror, so, once reflected, they are carried into the concave lens b, and the refraction is not diminished as a result.

The convex lens is placed in the tube d, to which the concave one is attached, for this reason: so that the polemoscope can be lengthened as is convenient and as the design requires. Yet in this optical instrument this is so far from hindering the exact presentation of the images of visible things (even if the instrument were drawn out to twice the length) that, on the contrary, it shows objects more clearly to the sight at a greater length than at a smaller one. Anyone, therefore, may have this instrument built, longer or shorter, at his own discretion, in the manner described above. As for my own, its diameter is 1⅔ inches, the longer tube 22 inches, and

the shorter equals eight inches. But, as I said a little earlier, the length can be varied: the shorter the tube, the smaller the images of visible things it gives.

The part e could be omitted altogether, were it not added so that access for viewing should not lie open to just anyone indiscriminately; and for this reason the figures vv and x — two small rings, namely u and t — have also been

[2]the letter at the open end of the elbow-piece is w; the faint letter on the thin disc, given as m, is not settled.

added. When all this has been properly observed, each glass correctly placed in its proper position, and the five parts tightly joined to one another by means of screws, the polemoscope is correctly built.

[Margin: What does the polemoscope do without lenses?] If the same polemoscope were deprived of its lenses, it would indeed still present objects, but in a small image, and it can scarcely reach more distant ones. Equipped with all its glasses, however, as we mentioned above, it sets both more distant and nearer visible things before the eyes clearly and distinctly enough. Indeed, this instrument could even be used without the two dioptric glasses, and with the tube a removed; but how it would present the visible images in that way I leave to your own experience.

So that you may learn its use more fully, note further that it matters a great deal what position the front mirror a holds relative to the rear one g. For according to the arrangement of the two, you will see all objects either erect, or supine, or inverted.

[Margin: That everything may be seen prone and erect in the polemoscope.] 1. First, if you wish to view everything erect and prone, the mirrors must be parallel to each other, as appears from diagram C, near A. Nor does it matter (when I put my eye to the small hole) whether I set the longer tube perpendicular, or the shorter one parallel to the horizon, or inclined upwards or downwards; or whether I direct both tubes, the longer and the shorter, parallel to the horizon. Moreover, although the hole is turned completely round, pointing inwards, there nevertheless occurs this difference in the objects seen: that everything is seen from behind.

[Margin: That everything may appear supine.] 2. But if you wish to view objects supine, the mirrors must be fitted and angled to each other so that they form an acute angle. This is done if one, correctly placed, is inclined to the other at 45°, and the small cavity is brought up to the side of the tube. Nor does it matter whether, in putting the instrument to my eye, I hold it parallel to the horizon or perpendicular, turned upwards or downwards, as can be seen near D and C.

Diagram. Engraved plate, *Fig. C.*: four panels showing the arrangement of the two mirrors of the polemoscope for different views, each panel lettered with a capital (A, B upper; C, D lower). Each panel draws the instrument as a right-angled frame: a horizontal tube a–d–b, a mirror set diagonally at the corner (d–g–h–e), a vertical tube running from the corner to an eyepiece end, and an object drawn as an upright tapered figure with its top o and foot u; dotted rays run from o and u to the mirror and on to the eye. At the eyepiece end of each panel a small triangle repeats the letters o and u, with f beside it, and an engraved eye looks in. In the upper panels the object stands beyond the left end of the tube and the eyepiece end is at the bottom of the vertical tube; in the lower panels the frame is drawn upright from the horizontal tube downwards, with the eyepiece end at the foot, lettered c. Signed at lower right in script *Autor. Sculpsit.* ("The author engraved it").

- A (top left): panel letter; upper part a, d, b, o, g, h, u, e; eyepiece end f, o, u
- B (top right): panel letter; upper part a, d, b, o, g, h, u, e; eyepiece end u, f, o
- C (bottom left): panel letter; horizontal tube b, d, a; mirror g, h, e; object o, u (to the right of the tube end a); eyepiece end f, u, o, c
- D (bottom right): panel letter; horizontal tube a, d, b; mirror g, h, e; object o, u (to the left of the tube end a); eyepiece end f, o, u, c
- Caption (foot, centre): *Fig. C.*

Blank verso of the plate leaf (the plate and type from another page show through in mirror image).

[Margin: So that everything is seen inverted.]

3. But if you wish to view objects inverted, turn the mirror round so that they incline inwards at right angles (as appears from B). This will happen if the opening is turned towards the inside and the instrument is set perpendicular to the horizon, pointing up or down, so that one looks in from behind; for the parallel position of this optical instrument does not invert the images of visible things but presents them upright, as was said before. Finally, from this variety in bending and turning the tubes there follow one way of seeing after another, which can be adapted to the varying situation of the place: practice will teach this to anyone.

For when one looks out from a breastwork into a ditch, or from a wall, or from a palisaded fence, or from behind some other cover, a longer polemoscope is needed. In this arrangement, admittedly, it will do nothing more, even if it equals several ells in length; yet the length serves this purpose, that either side among the enemy, besieged and besiegers alike, can survey the other conveniently while under cover.

[Margin: To enclose the polemoscope in walking-staffs.]

Among the other advantages that this optical instrument offers a soldier or a military tribune, this is not the least: it can be enclosed in a walking-staff and measuring-rod and carried about hidden, so that, wherever it is needed, it can be drawn out of it; it can afterwards be extended further and lengthened to as much as eight feet. Let its diameter be 1⅔ inches long, and the curvature 2 inches; the length each person will determine at his own discretion. But one thing must not be forgotten: because the tubes are lengthened, the mirrors must correspond to one another exactly. Unless this is done carefully and circumspectly, objects will be perceived by the eye with little accuracy.[3]

Moreover, anyone who has several mirrors arranged together in their tubes in the manner just described will see more than half of a round or angular body, or of some column, and what is happening in that place. Indeed, he will also devise other similar contrivances for bringing more remote and hidden bodies into view, especially if he is practised in catoptrics and dioptrics.

[3]the fraction after 1 in the diameter is ⅔.

Finally, as concerns the demonstration of this polemoscope, namely why, at particular inclinations of the mirrors, objects are presented sometimes upright, sometimes supine, sometimes inverted; and why also a different placing of the polemoscope, or

parallel or perpendicular, inclining upwards or downwards towards the horizon, varies the images of visible species: anyone versed in catoptrics perceives the reason for it. But so that the less experienced too may learn without trouble to understand the foundations of this science, I shall first set out some definite catoptric principles, from which the demonstration itself can afterwards be drawn.

[Margin: Catoptric principles, from which the demonstration of the polemoscope follows.]

I. Because of the smoothness of a polished and burnished body, rays falling on its surface are reflected (Witelo, Theorem 1, book 5; and Maurolycus [Francesco Maurolico], *De lumine et umbra*, Theorem 25, book 1).

II. Rays are reflected in mirrors at no other angle than the one at which they fell, because nature always takes the straight and shorter path. That is: the angle of reflection is always equal to the angle of incidence (Witelo, Theorems 10 and 20; Ibn al-Haytham, book 4, numbers 10, 18; Antonius de Dominis [Marco Antonio de Dominis], chapter 2, page 3; Maurolycus, Theorems 27 and 29).

III. Whatever is seen by reflection is seen in one place only, namely the place on which the reflection falls (Witelo, Theorem 24, book 5; Antonius de Dominis, chapter 2, number 8).

IV. The perpendicular ray is not only reflected back into itself but is also the strongest of all; and the rays nearer to it are likewise the more powerful (Euclid, *Catoptrics*, Theorem 2; Witelo, Theorems 11, 12, 13, 14, book 5, and Theorem 47, book 2; Ibn al-Haytham, book 4, numbers 10, 11 and 12; Antonius de Dominis, chapter 7).

[Margin: Application of the principles to the demonstration of the polemoscope.]

[Margin: 1. In upright form.]

1. From these four principles it is not difficult to demonstrate what follows. In diagram C, near A, let a b c be the polemoscope, d e one mirror in the bent tube, and the other mirror under the small cavity c f; the perpendicular object is o u. From these two points two rays fall on the mirror d e at g and h. Now, since it is certain that the angle of reflection is equal to the angle of incidence (as the second principle of catoptrics taught a little before), it follows that if these two points fall on the mirror d e at a single angle of 45°, then after reflection they necessarily fall at the same angle on the mirror c f, so that each ray at its point of incidence forms, as it were, a right angle of its own, as appears from g and h; for the point o of the object is reflected into itself at f in the lower mirror,

and u at c. And therefore, when I look at it through the opening, in its true form, namely[4]

upright and perpendicular, it appears to me, provided, that is, that the mirrors face each other in a parallel line. And in this way direct vision comes about.

[Margin: 2. In inclined form.]

2. As for this kind of vision, it is shown in C and D. For from it one sees that the mirror is turned round and that the eye looks in at the upper or the lower part. So the rays in the lower mirror appear not direct, as before, but plainly inclined, o towards the left (in figure C) and u towards the right, and hence the object is seen supine. The same happens at D with the instrument turned round, so that o is presented on the right side and u on the left.

[Margin: 3. In inverted form.]

3. How inverted vision comes about cannot be obscure from figure B. For since the lower mirror is completely inverted and the eye must be applied to the inner part, the lower point u of the object falls on the mirror c f and becomes the upper, while o, which was the upper, is lower with respect to the eye. But since these things are easy to understand, we do not wish to be more long-winded here. Now that this chapter has dealt sufficiently not only with the polemoscope but also with the other tubes, and above all with the telescope, it remains to teach also how the telescope is to be conveniently applied to observations of the stars, and what has been discovered in the heavens with its help within a few years; all of which will be discussed more fully in the following chapters.

CAPUT III.

Chapter III.

On the observations of the celestial bodies in general, made by the ancient and the more recent astronomers alike, and especially on observations of the fixed stars with the aid of the telescope, with a singular use and method of making them.

[Margin: The origin and progress of astronomical observations labour under much imperfection.]

Although the ancient astronomers, among whom the most distinguished were Meton, Aratus, Aristillus, Timocharis, Calippus [Callippus], Aristarchus, Hipparchus, Menelaus, Ptolemy and

al-Battānī, devoted themselves with tireless labour to observations of the celestial bodies, and, using instruments prepared at no small expense — namely parallactic rules, zodiacal armillaries, quadrants, radii, astronomical rings, torqueta and others — toiled hard to determine correctly the motion of the stars, especially of the fixed stars, together with their longitudes, latitudes and distances, they nevertheless did not leave us an astronomical table [abacum Aſtronomicum] complete in all its parts, either as regards the motion of the fixed stars

[4]on line 32 of the page the letter before *f* is a c, with no eye bar, not an e.

and the precession of the equinoxes, or as regards the length of the tropical and the sidereal year. This is clearly shown by later, accurate observations, which do not agree with the earlier ones at the due point; the fixed stars observed by Hipparchus and published by Ptolemy in his great astronomical work prove it well enough. So one may easily gather from this that the greatest cause of this defect is to be ascribed to imperfect astronomical instruments.

[Margin: The most noble Tycho Brahe was the restorer of astronomy.]

And although Copernicus, a hundred years ago and more, brought great diligence to this sidereal science through his observations — so as to examine the observations of the ancient astronomers and, if these happened to stray from the heavens, to construct more correct tables of the celestial motions — nevertheless, because he too was equipped with small instruments, for the most part wooden, he too was unable to bring astronomy to perfection. That waited until the most noble and most celebrated Tycho Brahe [Ticho Braheus], within our fathers' memory, devoted himself to this study and brought to it excellent and varied instruments, mostly of metal and skilfully made (such as simple and azimuthal quadrants, parallactic instruments, zodiacal and equatorial armillaries, the bipartite arc and others, which are found drawn in his *Mechanical Astronomy*). For with these instruments of proper size and more exact workmanship he observed the motion of the stars for a full thirty-eight years, and he completed the work not without enormous benefit to astronomy, as experience has taught all the best experts in the stars. For, in the first place, the motion of the fixed stars — somewhat different from the observations of the ancient astrosophers — this incomparable astronomer de-

tected: namely, that they advance one whole degree in the order of the signs within 71½ years — not within a hundred, as Ptolemy taught, nor within 66 years, as al-Battānī held. Moreover, by observing with the utmost diligence, he investigated and recorded the longitudes and latitudes of all the fixed stars (of which 1,022 were known to the early astronomers), and corrected whatever was erroneous; he also determined the true length of the tropical and the sidereal year. Unlike the ancients, he laid a foundation for the celestial motions that was not slippery. They tracked the longitudes of the fixed stars either by Sirius, or by eclipses, or by the Moon covering some small star, or, like Hipparchus, by the Moon's distance from the fixed stars. He, by contrast, took a surer road: in the daytime he measured the interval between Venus and a star of Aries, and through this fixed star proceeded to the rest. In this procedure he was obliged to take account of parallaxes that are not intricate [non intricarum Parallaxium], as Tycho himself relates in book 1 of the *Progymnasmata*, p. 103, which the lover of the stars may consult.

Accordingly, the immense labour of so great a man, his incredible diligence and the utmost industry he applied in these astronomical observations to restoring the motion of the stars exactly and handing it down to posterity, cannot be praised enough. Only one thing would have been to be wished: that the telescope had been invented in his time and its use become known. For then

he would have made the catalogue of the fixed stars far larger, and enriched it not merely with a hundred but with a thousand fixed stars, since the number of fainter stars scattered throughout the whole heaven, which not even the lynx-eyed can see with the naked sight of the eyes, is enormous, as observation and attentive inspection of the fixed stars through the optical tube will sufficiently teach anyone.

[Margin: Galileo, with the help of the telescope, discovered a great many stars in various asterisms.]

These nebulous and unknown stars were first discovered with the help of the perspicillum, and revealed to the whole world, by the great Galileo Galilei [Galilæus de Galilæis], as appears from his *Sidereus Nuncius*, where he writes on pp. 31 and 32 that to the six stars of Taurus called the Pleiades (since the seventh almost never appears) he added 36 others, and also noted their intervals, their magnitudes and the distinction between the old stars and the new, with the help of his excellent telescope. Thus, even if by the ancients three

stars only were observed and recorded in the belt, and six in the sword of Orion, he nevertheless added to them 80 [stars] seen with the same tube. What is more, with the same telescope he saw 21 further stars standing beside the nebulous star in the head of Orion, which is scarcely visible to the keenest sight, and likewise 36 others beside the nebula of Praesepe.[5]

I too, not once but many times, have repeatedly seen the same crowd of little stars in these asterisms with my telescope, and found that they really are there. Indeed, whatever stars in the heavens one chooses to view through a properly constructed optical tube, others at once plainly appear around them, more numerous and smaller, of various magnitudes yet bright and distinct with their own rays, surrounding the larger ones. Just as such observations of stars through the telescope are most delightful to behold and wonderfully affect the eyes, so they rightly stir every diligent lover of the stars to strive to seek out and carefully observe a like abundance of little stars in the other asterisms of the heavens as well. I too, equipped with telescopes of good quality, have long been captivated by the same love and desire of contemplating the stars of heaven. For after my optical tubes had often properly discovered and shown me the four companions of the planet Jupiter, I went on with the greatest eagerness to track down other stars too.

[Margin: In the asterism of Aquarius, between the first star of the outpouring of the water and the first bend of the water, of the two following, I noted a cluster of 33 little stars.]

So in the year of Christ 1642, in August and September, and likewise in October of the following year 1643, I not only examined through the telescope Jupiter and its satellites, which were then lingering in the starry sign of Aquarius, but also directed the telescope at the neighbouring stars, and above all at those that lie between the first star of the outpouring of the water, of the fourth

[5] in *vix viſus acie ſit conſpicua* the verb is *ſit*: its first letter carries the crossbar of an f.

magnitude according to Bayer's *Uranometria*, and the star in the first bend of the water, of the two following ones of the fifth magnitude; I have marked these by A and C in the diagram below. In this space of the sky I observed with the same telescope still other little stars of various magnitude and colour, 33 in number. For although only seven are found in this region of the sky on Tycho's celestial globe and in the same Tycho's canon of the restored motion of the fixed stars, I nevertheless counted far more of them, namely forty, and took great pains that the longitudes, latitudes and distances of each one

Diagram. An engraved star chart, Fig. D, set sideways on the leaf. Its title reads: *Part of the constellation of Aquarius, with new fixed stars observed in it. Danzig, in the year of Christ 1642.* A graduated scale runs along one long edge, labelled *Ecliptica* ("the ecliptic") and numbered from 6 to 15 in the sign of Pisces (♓), with a ♓ sign at each end; the figure beside the first ♓ is not legible on the scan [?]. The field shows a scatter of stars of several sizes. Seven larger stars are lettered A to G, and a key on the plate names them:

- A: the first star of the outpouring of the water, so called by Bayer, 4th magnitude.
- B: in the first bend of the water, the preceding of the two, 6th magnitude.
- C: in the first bend of the water, the following of the two, 5th magnitude.
- D: the more southerly, 5th magnitude.
- E, F, G: the three following stars, joined together, 5th magnitude.

A second key gives their positions:

Star	Longitude	Latitude
A	6° 40′ ♓	0° 19½′ S
B	9° 36′ ♓	1° 40′ S
C	12° 14′ ♓	1° 0′ S
D	12° 9′ ♓	2° 49′ S
E	11° 19′ ♓	3° 58½′ S
F	11° 47′ ♓	4° 10′ S
G	11° 50′ ♓	4° 44′ S

Around a group of stars near C, a set of concentric circles is drawn, with the sign of Jupiter (♃) entered at four places, each dated: *Die 29 Decemb. A. 1642* (29 December 1642), *Die 4 Sept. Ao. 1642* (4 September 1642), *Die 12 Sept. Ao. 1642* (12 September 1642) and *Die 4 Januar. A. 1643* (4 January 1643). Small italic letters stand beside several stars near the circles: h, b [?] and three further letters that are not legible on the scan [?]. Along the foot of the plate stand *Fig. D.* (left) and the engraver's line *Autor Sculpſit* ("The author engraved it", right).

- Labels read: the title; the A–G key and position key; *Ecliptica*; scale figures 6–15 and the ♓ signs; star letters A, B, C, D, E, F, G; the four dated ♃ entries (the fourth partly); *Autor Sculpſit*; *Fig. D.*
- Labels not read: the figure beside the first ♓ on the scale; three of the small italic letters by the circles, and the second is uncertain.

Diagram. A second engraved star chart, Fig. E, set sideways on the leaf like the preceding one. Its title reads: *Part of the constellation of Pisces, with new fixed stars found in it, in the year 1643, on 2 October.* A graduated scale labelled *Ecliptica* runs along one long edge, numbered from 14 to 22; no zodiac sign is engraved on the scale. Stars of several sizes are scattered over the field, and five larger ones are lettered A to E. The key names them:

- A: the preceding of the two small ones, 6th magnitude.
- B: the following of them, towards the south [Auſtrum], 6th magnitude.
- C: after the bend, the preceding of the three, 5th magnitude.
- D: the middle one, 5th magnitude.
- E: in the northern cord, at the joining, the preceding one, 5th magnitude.

A second key gives their positions, each line closing with the star's letter:

Star	Longitude	Latitude
A	13[°] 1[′] ♈	1[°] 31[′] S
B	14[°] 22[′] ♈	4[°] 19½[′] S
C	18[°] 9[′] ♈	3[°] 3[′] S [?]
D	20[°] 32[′] ♈	4[°] 40½[′] S [?]
E	22[°] 48[′] ♈	1[°] 38½[′] S [?]

Two positions of Jupiter (♃) are marked among the stars, dated *2. Octob.* (2 October) and *6. Octob.* (6 October). Along the foot of the plate stand *Fig. E.* (left) and *Autor Sculpſit* ("The author engraved it", right).

- Labels read: the title; the A–E key and position key; *Ecliptica*; scale figures 14–22; star letters A, B, C, D, E; the two dated ♃ entries; *Autor Sculpſit*; *Fig. E.*
- Labels not read: none wholly; the direction abbreviation in three position lines is uncertain.

I should determine accurately and enter on the chart in their proper order; all of these I show in the accompanying figure D. Next, near the very small star B, the preceding of the two in the first bend of the water (even though it is so tiny that it can scarcely be made out by someone gifted with the keenest sight), I detected with the tube nine more, and in addition, towards the left, following the order of the signs, five further, separate ones, close to the known star C of the fourth magnitude, between the 12th and 15th degree of Pisces. Among these, one is so small that it can be seen only through an excellent telescope.

[Margin: In the asterism of Pisces I noticed 21 small stars.]

I shall, however, treat these five very small stars, newly found by me in the heavens, more fully in the following chapter, especially since the letter of Father Antonius Maria de Rheita, which he wrote to the most distinguished Puteanus [Erycius Puteanus] on 1643 January 6 [*poſtridie Nonas Ianuarii*], as it were invites me to this undertaking. Besides these, in the asterism of Pisces (to the contemplation of which Jupiter, moving in that part of the zodiac, roused me) I observed other new and previously unknown small stars, twenty-one in

number, namely between A, the preceding of the two small ones, of the sixth magnitude, and E in the northern cord, the one preceding from the joining; whereas only five of them had been seen by earlier astronomers. I have also computed and added their longitudes and latitudes, with no less effort than those of the preceding stars.

[Margin: Mathematicians have so far been unable to see the fixed stars through the optical tube as round and without rays.]

In these observations, however, one point above all deserves consideration: why the other astronomers, equipped with telescopes, see all the fixed stars — both those known before and recorded on the celestial globe and those newly found and not visible to the naked eye — not in such proportion and size as the planets and other objects otherwise appear; whereas without the tube the stars known hitherto appear generally larger, on account of the rays and their adventitious light. Moreover, these stars are seen in no other way, both with the telescope and without it, than toothed, radiant, twinkling, sometimes even not round, and coloured, but by no means flat and without rays, as the Sun, the Moon and all the other planets are, except the Jovian ones. From this one may indeed infer the very great and almost incredible distance of these stars from the Earth, since the optical tube, in enlarging

the size of things, can achieve nothing, even though it enlarges the magnitudes of the Sun as well as of the other planets (which are also removed from us by some thousands of semidiameters of the Earth). This is Galileo's view, and the other mathematicians are of the same opinion: that through the same tube in which the planets and the other round bodies are seen in no other shape than precisely this one, the fixed stars nevertheless do not appear rounded. One is therefore led to wonder why Galileo and others, who did not lack excellent telescopes, never saw the fixed stars round, free of rays, and endowed with some larger size; whereas I, on the contrary, have quite often found them round with my tubes, and can always view them so whenever I please. Those who have used my tubes and have seen the stars in this round form will bear witness to it.

[Margin: How the telescope is to be fitted so that at any time the fixed stars appear round and stripped of adventitious rays.]

But I certainly fit my telescopes in a different way when I contemplate the fixed stars with them than when I apply them to the planets Jupiter, the Sun, Saturn or the Moon. This way of fitting the tubes and adapting them to the purpose will seem very easy to anyone to whom it has once been shown; yet it is not to be valued lightly, since men so great and so perspicacious have by no means noticed it until now. For even if Galileo, with a sheet of paper pierced by a hole and held to the eye, saw the fixed stars round and deprived of their adventitious rays, in this way they came into view extremely small, so that sometimes they escaped sight because of their excessive smallness. Otherwise it is certain that Galileo could never see the fixed stars round with the tube, as his words in the *Sidereus Nuncius* [Nuntio Sidereo], p. 30, testify: "The fixed stars," he says, "are seen to be by no means bounded by a circular periphery, but

like certain flashes vibrating their rays all around and twinkling strongly; they appear, in short, endowed with the same shape with the spyglass [Perſpicillo] as when they are viewed with natural sight." Nor were other mathematicians able to achieve this with their telescopes, Hortensius [Maarten van den Hove] among them. For in his dissertation on Mercury, p. 37, he writes as follows: "That the telescope does not cut off all the adventitious rays of the stars comes from nowhere else than from their strong radiation, as in the fixed stars, Mars and Mercury, in which the smallness of the body also causes them never to appear exactly round and bald, but always hairy, etc." Kepler likewise denies any size of the fixed stars, under

the appearance of a round body, to be revealed by looking through the telescope; and he asserts that the more perfect the instrument, the more the fixed stars are represented as mere points, from which bright rays go out in the form of hairs and are scattered — as he adduces in these words. Herigon [Pierre Hérigone], book 2, *Theor. Planet.*, p. 619.

But I, as was also said a little earlier, can conveniently view the fixed stars as round through my tube, and others will see them in that shape too, provided an excellent tube is at hand and they know how to handle it properly. For they appear not only round, as they otherwise look when viewed through perforated paper, but also fairly large, in due proportion for fixed stars [ſecundùm proportionem inerrantium]. So proceed with the tube in this simple and easy way. Take a tube that is fitted for observations of Jupiter and the Moon, and make the aperture next to the convex lens narrower; or put on a new paper whose hole has a circumference equal to a large pea, or let the hollowed-out opening match, all round, the smallness of the figure set here, drawn into a circle:

Diagram. A small figure of two concentric circles, set within the line of text, showing the size of the hole to be cut. It carries no letters or numerals.

When this is done, view fixed stars of the first or second magnitude with the telescope, and you will find them exactly round, visible in their own colour, and each decidedly larger than another. For Arcturus will appear larger than Aldebaran, Aldebaran larger than Cor Leonis, and so on in order, so that no one could view them without wonder.

[Margin: For which stars is a small hole suitable, and for which a larger one?]

This small hole, then, can be used above all for viewing those stars that are endowed with a stronger light, for example Venus, Sirius and so on. But for stars of fainter light, such as Aldebaran and others, a somewhat larger hole is suitable, and it is preferable to the narrower one. If, however, you wish to track down and detect with the tube those lesser new stars, of which there is a huge multitude, a wide hole is most suitable; with it only this is lacking, that the stars viewed through it do not appear round. A hole of this kind is likewise suitable for viewing the spots of the Moon. Therefore, the stronger the rays the stars dart, the smaller the hole that suits them, yet not so that it falls below

the smallness of the cavity already drawn. With a small hole of this kind the adventitious rays can also be removed entirely from Mars and Mercury. And,

although Venus has a very brilliant light, especially when she is full of light, around her apogee, and stands nearer the Sun, where she darts her strongest rays, I have nevertheless, in the way already described, both stripped her adventitious rays and seen her perfectly round. Here too I must point out something that I consider not unworthy of notice: the Moon viewed through this small hole is seen only faintly and shows little light through it; but when this small hole is removed and the larger, original one put back, everything on the Moon can be examined distinctly and clearly.

[Margin: How the diameters of the fixed stars can be observed.]

And although this method of observing the fixed stars requires less work and diligence, I am nevertheless persuaded that in future the visible diameters of the fixed stars can be determined in this way more surely and more readily, and their proportion relative to the planets Venus, Jupiter and Saturn investigated more exactly than with the naked eye.

[Margin: Why do the fixed stars and some planets twinkle so strongly, and so enlarge their diameters?]

On this occasion, however, someone may perhaps ask how it comes about that the fixed stars, like Venus and Mercury as well, twinkle so strongly and appear larger than they really are. To this I reply that these celestial bodies are endowed, beyond the rest, with a brighter, sharper, more prominent and more penetrating light, and therefore produce a greater reflection in the opening of the pupil; this is why they shine out brighter and larger than the other, less brilliant bodies. Galileo agrees with this, saying: "The more vivid the light of objects, the more they seem to be diffused." That the fixed stars dart their rays with so tremulous a motion, and display a stronger light than most of the planets, has without doubt this cause: they do not borrow their light from the Sun, but have received a native light, their own, from GOD.

[Margin: Why do the fixed stars appear larger than they really are?]

From this the reason can also be understood why the fixed stars that abound in many adventitious rays (such as the Great Dog [canis major]) and come into view appear to us larger than Jupiter himself, but once their hair of rays is taken away at once turn out smaller than Jupiter, whose light is not so brilliant and penetrating but weak and moderate. Thus Sirius is seen only somewhat larger than Aldebaran, although in bulk (if the bare sight of the eyes is to judge here) Sirius appears three times larger than Aldebaran; and it is that diffused hair of rays that produces this apparent magnitude.

I met with an example of this kind on the evening of 1644 March 22, at the seventh hour, when I saw Jupiter in conjunction with Venus, the one planet about 45′ distant from the other, and both almost equally near the Sun. Venus, however, appeared much larger than Jupiter: first, because she was nearer the Earth; and second, because she enjoys a brilliant and diffused light, from which arise the adventitious rays that formed a larger radiance of Venus in my eyes,

so that the difference in magnitude between the two planets seemed to me incredible.

[Margin: Venus viewed through the telescope appears much smaller than Jupiter.]

But once I had stripped Venus of her hair of rays with the telescope, she was so far from being seen larger than Jupiter that she was seen rather smaller than him. Accordingly, we can sometimes be deceived by the strong light of the stars into judging a starry body large which is in reality smaller, especially when the bright light of this smaller celestial body is deficient; for then the adventitious rays grow all the more, according to this rule of Galileo in the *Sidereus Nuncius*, p. 32: *"The increase of light grows more and more as the smallness of the luminous bodies decreases."*

Furthermore, with the help of this telescope one can also learn what the Milky Way [via lactea] is, which, whenever the sky shines clear, is always seen in a particular region of the heavens. Philosophers, and the Peripatetics above all, have left us a great many disputations and lengthy commentaries on it, in which some hold it to be a meteor [meteoron], others something different from this. Now, however, thanks to the telescope, it is certainly established that the Galaxy or Milky Way is nothing other than a dense heaping-together, a huge mass, of innumerable tiny stars, among which very many fairly large and highly conspicuous ones appear, as anyone equipped with a good telescope may see with his own eyes.

[Margin: The Milky Way is a mass of innumerable small stars.]

But someone may ask here how the observation of them is to be undertaken. Let him know that this aim can easily be reached, provided a fine telescope is at hand. For if the telescope is directed by hand at any region of the sky whatever, little stars of this sort will frequently pass before the eyes of a diligent observer, especially if he has grown used to this labour of observing by frequent practice. The unpractised will experience more toil and weariness here, so that they sometimes begin to tire before a single

[Margin: The method of exploring how numerous the unknown stars are.]

tiny star is tracked down by their searching, because they cannot hold the optical instrument motionless.

Hence, although tiny stars of this kind sometimes come into view, they vanish again and become invisible because of the shaking of the optical instrument before they can be properly examined and counted. Such observers should therefore be advised to have a special instrument made for themselves; once the telescope is placed in it and properly set up, anyone will be able to inspect and contemplate, at his own discretion, these tiny stars and many more besides.

[Margin: The construction of an instrument on which the telescope can be placed, so that any star whatever can be viewed with the armed eye and accurately examined.]

The most ingenious Master de Cartes [Descartes] did indeed describe such an instrument in his *Dioptrics*, p. 132; but, so that it might serve my own

purposes, I have reduced it to a more convenient form. And since it is not so very difficult to obtain, I shall set out its diagram here for the benefit of the lover of the stars [Astrophilus], and at the same time indicate briefly how it is to be built in all its parts.

The instrument consists of separate members that are fitted neatly together, as will be clear from the figure placed alongside. It has, namely, four feet, which rest on a cross-shaped base [fulcrum decussatim ordinatum] and support the part b. Four pulleys [trochleae] are attached to the cross-shaped base, which allow this instrument to be set firmly on any floor. Again, b is for the most part hollowed out, so that the piece of wood i, with its long rounded shaft, can move in it, and the instrument itself can be extended. And so that it stays extended, a pulley is fitted to the side of i, so that i can not only be drawn out further or, as the case requires, drawn in, but can also be made fast by the pulley. Likewise the upper part c consists of hollowed pieces of wood, so that the round piece of wood d in it too can be turned and directed conveniently to any side without any shaking of the stand, and can nevertheless be made steady by the pulley c. As for the other piece of wood e, larger and longer, you will move it up and down in the hole of the upper part d, according to whatever difference of position the star to be viewed inclines towards, and you will likewise make it fast with a pulley in the arc f. The telescope is laid on this piece of wood e, which is somewhat hollowed out in its upper part, and is tied on with a cord. But if the star stands at an altitude of 80° or 90°, the instrument must be drawn out further and raised upward until

Diagram. A full-width engraved plate occupying the upper two-thirds of the leaf, marked *Fig. F.* at lower right inside the frame: the observing stand for the telescope described on the preceding page. Against a night sky with clouds and scattered stars, on a terrace closed by a balustrade, a long telescope tube lies along a wooden beam, which is pivoted on a block at the top of a tall post. An arc runs below the block, and a quadrant with a graduated edge and a hanging plumb-line is fixed under the beam. The post is made of stacked cylinders, the upper two each fitted with a wing-screw, and stands on four splayed legs over a cross-shaped base; a wing-screw is set at each foot of the base. At right an observer in a fur cap and a long gown holds the tube at the eyepiece and looks up through it. In the foreground lie loose parts of the apparatus: a ball set in a disc on an upright board, a second ball on a rod, a ring, a floor board with a round hole and bolt-holes, several loose screws, a rod, an elbow-shaped piece and a cylinder with a wing-screw.

- [?] (side face of the beam, near its upper end): a small letter, read as c or e and not separated
- e (on the beam beside the tube)
- d (on the block at the top of the post)
- f (beside the arc below the block; the letter is partly lost in the hatching)
- c (upper cylinder of the post, with wing-screw)
- i (lower cylinder of the post, with wing-screw)

- b (square post above the stand)
- l (upper edge of the board behind the stand)
- k (the ball set in the disc on that board)
- k (the loose ball lying behind the stand)
- m (the loose ring on the floor)
- [?] (two thin strokes on the floor board, at its left end and its middle; possibly l, not resolved)
- d (the loose elbow-piece, lower left)
- c (the loose cylinder with wing-screw, lower middle)
- *Fig. F.* (lower right, inside the frame)

The small numerals on the quadrant's scale were not read. Below the plate the leaf is blank.

Blank leaf (the back of the plate with the plate and the facing text showing through in mirror image).

without bending his body too far, the observer has fitted the telescope suitably to the star's altitude — something that can be achieved without difficulty with the help of this instrument. Moreover, a quadrant, larger or smaller, can also be joined to this part e of the instrument, so that the star's altitude becomes known precisely at the same time and there is no need to hold the quadrant in the hand. In this way you will not easily falter while observing; instead, the star's altitude will be shown to you on the quadrant without hesitation. For once this instrument has been set suitably to the desired place of the star, as its position demands, and the star sought has been found, it should be made fast at once with the pulley [trochlea]. The plumb-line, being thus motionless, will mark on the quadrant the degree of the star's elevation; whereas a quadrant held in the hands wavers easily, so that the degrees too, especially on a small quadrant, usually nod this way and that as well.

CAPUT IV.

Chapter IV.

On the observations of the planets, chiefly of Saturn, Jupiter, Mars, Venus, Mercury and the Jovian stars, both the author's own and those of some other leading astronomers: where it is also briefly shown that those five new stars recently noticed by Father Antonius Maria de Rheita, which he calls Urbanoctavian and contends are circumjovial, were in reality not Jovian, but for the most part new, unknown fixed stars.

[Margin: A later age always brings something new.]

If, in the time of the ancient philosophers, anyone had been found to teach that not all the planets are round, nor seven in number, but that eleven, and perhaps even more, are to be found, and likewise that Mars, Venus and Mercury wane and wax in their light like the Moon — to say nothing of other new discoveries of the science of the stars — his doctrine would certainly have been rejected as utterly absurd and utterly foolish, and the man himself would no

doubt have been taken for simple, uncouth and ignorant. But once optical tubes had been invented, and their use, by far the most valuable,

had been recognized and applied to the contemplation of the celestial bodies, the opinion just stated is not counted among paradoxes by the mathematicians, because these and other marvellous phenomena are uncovered with the help of the noble telescope — however much the Peripatetic philosophers still doubt the certainty of the matter. I have therefore decided to review briefly in this chapter the observations of certain distinguished and trustworthy mathematicians concerning the planets just mentioned, and to add to them my own, which I have obtained by inspecting with my eye through the telescope and have found to be entirely true.

[Margin: Through the telescope Saturn has so far appeared first oval, then composed, on either side, of two little globes in addition.]

As for Saturn first, then: from remote antiquity onward he was held to be round, the testimony of the eyes themselves not contradicting it. But once he began to be viewed with the armed eye, he appeared nearly oval, as Kepler and other mathematicians attest. As soon as this optical instrument had been made more perfect, however, Saturn, viewed from day to day through a more elaborately made telescope, appeared not only oval but furnished with two little globes adhering on either side, so that he seems to be composed of three parts, as is plain from the present figure G, at B. I have very often seen Saturn in this form, namely in October and November of the year 1643: for the most part the two adhering little globes were parallel to the ecliptic.

[Margin: The two little globes adhering to Saturn seem to be two stars going round him.]

I am, however, wholly of the opinion that Saturn does not always appear oblong, and indeed pointed with two small globes, but that at times these globes lie hidden behind Saturn, as if they were two stars (and indeed at fixed times) that go round Saturn. For I remember that in September and October of the year 1642 I saw him perfectly round, and that on separate occasions. The most eminent philosopher and astronomer P. Gassendi also observed the same figure in Saturn, at Paris, in August of the same year, as stands in his judgement on the nine stars seen around Jupiter, p. 14. And he reports in the same place that Galileo, 30 years before, had also viewed him in such a round figure with his telescope. Besides this, Matthias Hirschgarter [Matthias Hirzgarter], in his *Detectio dioptrica*, records concerning the same star of Saturn

Diagram. Figure G: a full-page engraved plate, the planetary discs drawn light against a dark, horizontally hatched ground. At top left, A: Saturn as a round body flanked by two broad, crescent-like handles that meet above and below it. At top right, B: Saturn as an oval body with a small round globe attached at each end. At middle left, D: Mars as a gibbous disc, its right-hand side cut off by a straight edge. At middle right, C: Saturn as an oval body enclosed within two pointed, lens-shaped handles, with the legend "Observed in the year 1645, in the months of September, October and November." At the

foot, centred, E: Jupiter as a large disc mottled with hatched shadings. "Fig G" is engraved at lower left, and the engraver's signature "Aut. Sculps." [the author engraved it] stands at the foot of the Jupiter disc.

- A (top left): SATVRNVS. — Saturn
- B (top right): SATVRNVS. — Saturn
- C (middle right): SATVRNVS. Obſervatus Anno 1645. Menſe Sept. Octob. et Novemb. — Saturn, observed in the year 1645, in the months of September, October and November
- D (middle left): MARS. — Mars
- E (bottom centre): IVPITER. — Jupiter
- lower left: Fig G — Figure G
- foot of disc E: Aut. Sculps. — the author engraved it

[Margin: Another face of Saturn, observed by the noble Fontana.]

that a leading and most noble gentleman named Fontana [Francesco Fontana] (as I learned that name from others) inspected this planet at Naples with an excellent tube, and observed it in a form wholly other than, and different from, that of the rest. For on each side, in place of the little globes already mentioned, he saw a bisected little handle lying beside the body, so that each handle was perceived by the armed eye as distinct from the true body, and through the hollow of each handle a view lay open into the blue sky and the aether — as is written in the already mentioned author, p. 22. I have set a face of Saturn of this kind into the present diagram G, and marked it at A.

[Margin: The true face of Saturn is described.]

To many, this report about the star of Saturn seems exceedingly astonishing and scarcely credible; nor do I deny that at first I withheld my assent. But after I had acquired longer and better tubes and had inspected Saturn through them, I found that the face of Saturn just described was not a mere dream, but that it is in fact seen so, in large part. In some respects, however, I noticed that his face was somewhat different from the one I set out a little before. For the middle body of Saturn, which is also the largest, appeared to me in a more oblong form, and the little arms on either side also looked to me different in part. They did not cling together so closely with Saturn's middle body; rather, where they should have come together and grown into one continuous body, they ended in so sharp and thin a point that it could not be perceived that they were tightly joined to Saturn's oblong body. Moreover, the space by which the little arms were in some way separated from the body of Saturn itself, through which one could look at the blue sky, did not equal the breadth that the earlier figure represents, but was smaller. Furthermore — and in expressing the true form of this planet this most deserves attention — each arc bounding the arms, the inner as well as the outer, gives by no means a section of a circle, as the excellent Fontana noted, but a parabolic, or rather a hyperbolic, section, as can be seen from figure C. For this is the true face of Saturn: I was able to view it accurately with a long tube of exquisite workmanship, and to consider everything properly, so that

everyone who is led by a desire to discover the truth may safely rely on this tireless observation.

[Margin: Why does Saturn's face not appear the same?]

If, however, someone cannot inspect and distinguish all these things so exactly with his own optical tube, which he judges to be no worse, let him know this. Even if these telescopes have been worked with the greatest care and perfection from a spherical section, and reach a length of six or even eight feet, they will nevertheless not show the face of Saturn just described in every respect. But even if they are the best of all, and yet do not exceed this size, they reveal no more than the two little globes set out above under figure B in place of the arms. For this business a somewhat longer tube is required, drawn out to at least eleven or twelve feet; and further, it must suffer from no imperfection and must be furnished with clear and finely polished lenses — something that such long tubes usually lack.

[Margin: What kind of bodies the little arms of Saturn are cannot yet be defined.]

But what kind of bodies these two little arms of Saturn are I cannot yet determine on this occasion: whether they are always seen with a face of this kind, like a waxing and waning moon, at the same distance from Saturn and of equal breadth; or whether they are in part round bodies which at definite times grow and shrink, vary their motion, and sometimes come nearer to Saturn, and sometimes are even entirely hidden. For this planet completes its period very slowly, and in addition it requires most careful observations over many years with the longer tube mentioned above, fitted with its own skilfully polished lenses. I therefore suspend my judgement and reserve this matter for another time. And so much, then, for Saturn.

[Margin: How does Jupiter's face appear?]

In the star of JUPITER, too, memorable things of more than one kind occur, observed with the help of the better telescopes. The globe of Jupiter is indeed seen not in an unusual and strange form, as Saturn is, but fairly round. Nonetheless one can detect that it is not perfectly round in every respect, nor polished like a turned and smoothed globe. For if I inspect it through my tubes (with whose help its diameter equals six, or rather nearly seven, digits), its disc

I find to be less radiant, and sprinkled with large and distinct spots, almost after the example of the Moon; these are seen to be far darker than the other parts.

I have tried to express this figure of Jupiter as carefully as could be done in the preceding diagram, at E. Because of the immense distance of Jupiter from the Earth, however, the telescopes in use up to now, even the most excellent of them, have not yet been able to make these spots out and to distinguish them from one another, as the spots of the Moon are distinguished. Meanwhile we hope that far more perfect telescopes, made from hyperbolic conic sections, will be brought forward, which will reveal the figure and form of the heavenly bodies still more openly and clearly.

[Margin: Jupiter is surrounded by 4 small planets.]

Moreover, it is now known to almost all learned men that this star of JUPITER is always surrounded by other small planets, which are called the Medicean Stars, the Jovials, the Circumjovials and the Companions of Jupiter, and which accompany Jupiter like satellites. These small circumjovial planets were first discovered by Galileo Galilei with his excellent telescope in the year 1610, as his observations published in the *Sidereus Nuncius* teach us. Shortly afterwards, moreover, Simon Marius [Simon Mayr] described these companions of Jupiter at length in his *Mundus Iovialis*, and likewise derived tables of their motions from his assiduous observations of them. And because observations of these Jovials are no less delightful than useful, I too, for that reason, kept watch for observations of them very frequently and carefully in the years 1642, 1643, 1644 and 1645. From these I noticed their wonderful and rapid motions, above all their close conjunctions, pleasant to the eye, and sometimes their eclipses.

[Margin: Where is the illustration of the Jovials and of the new fixed stars to be found?]

I have therefore set out each and every observation of these Jovian planets in a number of figures, keeping due proportion throughout, just as I have also presented and added, at the end of this treatise by way of an appendix, an illustration of the small new fixed stars that were seen around Jupiter. These observations were continued daily whenever the clearness of the sky allowed, so that I sometimes repeated these observations five, or even six, times in one night; and to each single observation also its own proper and true time, together with a description of the position

of the Jovials. So far as I know, no one since Galileo has yet done this in such a form.

[Margin: Observations of the Jovials serve for investigating the longitudes of places.]

Meanwhile it would be seriously to be wished that such observations of the Jovials had been undertaken more often by students of astronomy before now, and were still undertaken every year. For in this way the longitudes of places can sometimes be investigated, because of the swift course of these companions of Jupiter: from conjunctions of the Jovials — especially of those nearer to Jupiter, which come about through contrary motion — observed in different and widely separated places, and from noting the time at which one is occulted by another (which can certainly be known from the altitude taken of some fixed star). Or at the least their motions can be examined and corrected. For although Simon Marius has already laid the foundations of these motions, he himself frankly admits on page 10 of the *Mundus Iovialis* that they have not yet been brought to their perfection, as would indeed be fitting. Therefore, since these conjunctions of the Jovials are not infrequent, no small benefit will flow from observations of them into the whole science of the stars.

[Margin: Observations of closer conjunctions and of eclipses of the Circumjovials.]

This spurred me to observe these pleasant and notable conjunctions quite often, both among the Jovials themselves and with Jupiter, as appears from the observations of the Jovials. For in the year 1642, on August 20 (New Style), at $11^h\ 40^m$, the small star B was covered by Jupiter; but at half past eleven, a time 10 minutes earlier, it was still visible. 2. On September 17, at $9^h\ 46^m$. 3. On September 20, at $10^h\ 44^m$. 4. So too on September 23 of the same year 1642 there was a conjunction of neighbouring Circumjovials, such that one entirely covered the other. 5. On October 4 a similar conjunction occurred. 6. On October 26, at $8^h\ 45^m$, as also on the following day, there was again a very close meeting of two of them. And such meetings happen quite often, as every student of astronomy will be able to see and to find out by observing.

[Margin: On the nature and property of the Circulators of Jupiter.]

For sometimes all four are seen in one straight line; sometimes one and another of them admit a small latitude; sometimes three form a single triangle; at times they appear larger. The cause of this varied appearance I shall explain a little later. For at the outset it must be known here that the four companions of Jupiter, and

newly found Circumjovials regard Jupiter as their centre and always accompany it, while keeping their own proper motion, whether that motion is direct, stationary or retrograde; so they are carried round Jupiter just as the other planets are carried round the Sun.

II. Next, that their motion is from west to east, in the order of the signs, while they move on the far side of Jupiter; and again, while they are carried to the near side, from west to east; and that they are seen continually in a straight line, now east of Jupiter, now west of it, because their orbits are parallel to the ecliptic.

III. Moreover, it should be noted that at times they have a small latitude, both northern and southern: southern, indeed, when they are farthest from us, and northern when they are nearest to us. This does not happen, however, at their greatest elongations from Jupiter, since they then proceed parallel to the ecliptic. And Simon Marius confirms this very point in the *Mundus Iovialis*.

IV. Further, that the Jovial Mercury always admits a greater latitude than the Jovial Venus, and she in turn a greater one than the Jovial Jupiter, and so on in order; yet in such a way that their latitude is never so great that they [?] above or below Jupiter.

V. Besides, it is to be observed that their periodic motion about Jupiter is unequal. For the nearer they are to it, the swifter they are; but the farther they are from it, and the closer to their elongations, the slower they go, so that they appear almost stationary.

VI. Further, it must be noticed that the one more remote from Jupiter, namely the Jovial Saturn, never deviates from Jupiter, toward the right or the left, by more than 13′ or 14′, and that it completes its whole circle in $16^d\ 18^h\ 9^m$. The Jovial Jupiter, by contrast, departs from Jupiter by only eight minutes

(8′), and completes its period in 7^{d} 3^{h} 57^{m}. The third, namely the Jovial Venus, recedes from Jupiter by only five minutes (5′), and completes its motion in 3^{d} 13^{h} 18^{m}. The last, namely the Jovial Mercury, goes off from Jupiter by only 3 minutes, and runs its course swiftly, within 1 day, 18 hours and 28 minutes, according to the Tables of Simon Marius, whose accuracy any astronomer will be able to test by my observations and by his own.

VII. Add that they lack light of their own, and receive it on loan from the Sun, not from Jupiter; and for this reason they suffer eclipse not only from Jupiter's body but also from its shadow.

[Margin: Why do the Jovials sometimes appear larger, sometimes smaller?]

VIII. It follows that I should give the reason why these satellites of Jupiter appear sometimes smaller and sometimes larger. I say, then, that the cause of this varying appearance is a vaporous sphere, which belongs to Jupiter just as much as to the Moon, and which is necessarily denser than the ethereal air. Therefore, when the Jovials are on the far side of Jupiter and its vaporous sphere lies in front of them, and they are farther from us, it follows that they appear larger to us than if they were moving on the near side of Jupiter and of its atmosphere. For it is established by the science of optics that all rays falling into a denser transparent medium are refracted towards the perpendicular; the angle of vision is thereby widened, and all objects appear larger, as is learned from Maurolycus, Book 1, Theorem, page 36, and from Witelo, Book 10, Theorems 35 and 41.

[Margin: An objection is met.]

But here someone might perhaps object to us that the contrary should rather be inferred from the greater distance of these tiny stars: for the more remote from us they were, the smaller they would appear, and the nearer, the larger. To this the answer must be that the distance and latitude of these Circumjovials need not be taken into account with respect to the Earth, as regards their orbits. For they recede from Jupiter by only a few minutes, and so so small a distance cannot make these companions of Jupiter twice as large; nor can ordinary refraction bring about any evident variation here, because this appearance of Jupiter's satellites occurs when Jupiter is raised higher above the horizon and freed from all refraction. And let this be a brief account of the nature and motion of these four new planets and Jovial stars. For I have been able to detect here no other number and no other motion, however watchful an eye I have always turned on contemplating them; nor, so far as I know, has any been detected by anyone else.

[Margin: The five [?] new planets added to the other 4 Jovials by the Reverend Father Antonius Maria de Rheita were not wanderers; rather, one of them was a fixed star in Aquarius, and the remaining 4 new, unknown star [?].]

Although, a few years ago, namely towards the end of the year 1642, Antonius Maria de Rheita, of a religious order, asserted in a letter written to the most distinguished Puteanus (whom I have also mentioned before) that he had found five further new Jovials at Cologne, and that they had been added to the

four already mentioned, nevertheless (if I may say so with his leave) haste in reaching a verdict threw him into error. For he took five new fixed stars to be five Jovial wanderers, as has been sufficiently demonstrated by the most distinguished P. Gassendi in his judgement on the nine stars seen around Jupiter. Yet someone might find one thing wanting in that judgement: that the distinguished Gassendi thinks these five stars are the ordinary ones in the asterism of Aquarius, which are also found marked on the celestial globe, and which I too placed among the fixed stars of the preceding figure D and marked with the letters C, D, E, F, G.

But the said Reverend Father Rheita, among these five fixed stars already mentioned, admitted only C into the number of the new ones; the remaining four belonged to the class of new stars, which are not seen with the naked eye unless an optical tube of superior quality is applied to it, as will become clearer from what follows. That the matter stands no otherwise, I am therefore amply confirmed by my observations of these small fixed stars, and I can make the kind reader entirely certain of it.

[Margin: The Urban-Octavian stars were seen and observed by the author earlier than by the Reverend Father Antonius de Rheita.]

For I too noticed them earlier than the Reverend Father already mentioned. On 1642 August 28, and afterwards on September 4, I observed those very stars, when I also found Jupiter in the same place, namely at 13° 20′ of Pisces, where the Reverend Father also saw it on December 29; and again on August 28 I saw it at 14° 15′ of Pisces, where the Reverend Father saw it on 1643 January 4. Let no one be surprised that it happened so: for at that time Jupiter was retrograde for me but direct for him; it was advancing from its station, moving in the order of the signs, and so I was able to see it in the place just mentioned earlier. Therefore, around this time, I examined Jupiter most diligently with the tube on every clear night, since I had resolved to continue my observations of the Jovials,

in which I also spent several months, as can be seen from the observations. There I not only directed a watchful and armed eye at the star of Jupiter and at its four companions, but also looked around to see whether more than these four attended it. Yet I could detect none of that kind, but only a number of unknown small fixed stars by which Jupiter was surrounded. For on the fourth day of September (which was December 29 in the Reverend Father's observation) I too came upon those five tiny fixed stars which the Reverend Father judged to be new Jovials, and I recorded on paper their position both with respect to Jupiter and among themselves, as will be clear from the attached diagram D, which has been inserted in the preceding third chapter. In it I also marked the place of Jupiter on September 4 and August 28, which correspond to the Reverend Father's observation on December 29 and January 4, as will appear from comparing his figure with mine. For no other difference is to be seen in it, except that Jupiter stood somewhat higher for him, because of its smaller southern latitude.

For the sake of better understanding, however, we shall keep the place of Jupiter that the Reverend Father observed, where, when Jupiter was seen on December 29, two small stars stood beside it on the right, namely c and h (in the earlier figure D). The small star C was not new, but one of the fixed stars, also marked on the celestial globe and known to astronomers, which Bayer [Johann Bayer] calls "the following of the two in the first stream of the water of Aquarius". The other, h, was new: a tiny fixed star unknown before this. On the left side of Jupiter there also stood three unknown small stars, namely i, k, l. These five small fixed stars the Reverend Father admitted into the number of the new circumjovials.

To prove this, I shall first distinguish them by definite circles and draw their true position, following the example of the Reverend Father and of P. Gassendi in his *Judgement* on these small stars; a picture of this kind is found in figure 1. For when, from the place of Jupiter on December 29 of the year of Christ 1642, I draw circles through all five of these small stars, I obtain at first the same number, five, except that for me l (in the present figure H) is the most remote, on the outermost circle — the star which the Reverend Father marked with the letter F, as figure 1 makes

Diagram. Engraved plate, signed *Fig. H.* at the lower left and *Aut. Sculps.* ("the author engraved it") at the lower right, carrying four numbered star diagrams in two rows, each drawn as a set of concentric circles about a central body.

- Schema 1 (upper left), headed "Schema, showing the new fixed stars observed at Danzig in the year 1642": concentric circles about the symbol of Jupiter (♃) at the centre, with a straight line drawn from l (upper left, on the outermost circle) through the centre to the lower right. Labelled stars: l, n, m, i, k, h, c (c drawn as a large star at the right, beside h). Small unlabelled circles stand on several of the circles, and a run of unlabelled small stars lies along the line between i and the centre.
- Schema 2 (upper right), headed "The Rheita schema, sent to P. Gassendi": an eye drawn at the top, from which dotted lines fan down across a circle divided by radii into the twelve signs of the zodiac, read round the rim as ♍ (top, under T), ♒, ♓ [?], ♈ (left), ♉, ♊, ♋ (bottom, over V), ♌, ♍, ♎ (right), ♏, ♐. Inside lie concentric circles and, at the centre, a small elliptical web of rings and spokes. Letters: T (top), F, R, N, G, L, b, H, K, D, E, X, I, V (bottom), C. L, K and I are small circles; the rest stand by stars.
- Schema 3 (lower left), captioned "The Rheita schema, sent to C. Lobkowitz [Juan Caramuel y Lobkowitz]": concentric circles about a large central star, divided by a vertical and a horizontal diameter. Stars lettered C, C, F, D, E, b, D, G, L, M, with an unlabelled run of small stars between the centre and b.

- Schema 4 (lower right), captioned "The preceding schema inverted": the same arrangement turned about, with stars lettered M, L, G, D, b, E, D, F, C, C.

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manifest; and in the next circle, the next-to-outermost, my C is his E; in the third circle, my h is taken by him as D; in the fourth, my k is the one the Reverend Father marked with the sign H; and in the inner circle, my i is the one he calls b — and it is indeed called a Medicean star, although it too was a fixed star, as I shall show more clearly a little later; and I shall also offer some remarks about his little star G. But if my diagram is to be compared properly with the Reverend Father's figure, his figure must be turned completely upside down, so that the lower side becomes the upper and the eye is turned upwards, because these little stars were observed by the Reverend Father in inverted order. Father Gassendi too showed this in his judgement on these little stars, and I shall shortly show it more fully myself. Once this is done, his figure will agree with my diagram in the greatest part. The only difference found in it is that my l stands a little higher than his F. But I am firmly convinced that here he strayed somewhat from their true position, which he could not determine very accurately from two observations, as anyone not inexperienced in celestial observation knows. The position of my little stars in longitude and latitude, on the other hand, I worked out with the greatest care from the true place of Jupiter at the passage of these little stars, and from its diameter and the aperture of the tube; and so I am certain that it is correct, for I did not rest content with one or two observations, but used many more. The old Jovial planets I entered from Father Gassendi's observation: one of them, indeed, had not so great a latitude as the Reverend Father assigned it — a matter on which more will follow later.

But someone may perhaps ask here how it came about that these little stars appeared to the Reverend Father to advance, and indeed, as he asserts in his letter, from west to east. I answer that the reason is ready to hand. 1. First, because he noted all these stars in inverted order, so that for him east became west; thus his saying that the star moves *from west to east* [ab occaſu in ortum] means nothing other than that it moves from east to west, as my figure plainly shows. 2. Because Jupiter was then direct, and therefore, following the order of the signs, departed by one degree of longitude from the place where on December 29

it stood still. So the Reverend Father could not persuade himself that Jupiter had advanced so far in so short a time, and therefore he preferred to believe that these pseudo-Jovials had moved forward, since their elongation from Jupiter had become so evident, as the adjoining figure makes plain. For when I set the places of the stars, taken from the asterism of Aquarius, together with the position of Jupiter (which it held with respect to them on 1643 January 4 of the Christian era) into this figure 1, at such an angle as if Jupiter had been stationary, then the very motion the Reverend Father imagined will appear: where, in

his view, H passed into I in the space of six days; according to my figure 1, however (namely k into o), I observe that this did indeed happen. 3. That E, which the Reverend Father calls the next-to-outermost, was the largest of all the pseudo-planets for him is entirely true: for it was a fixed star of the fifth magnitude, marked by me with the letter C. And it is truer than true, too, that some of these fixed stars appeared larger than the old Jovials, especially i among the others. 4. Further, that the little star F, as he writes, eventually vanished is also consistent with the truth: for since Jupiter drew closer to it on January 4 (and it is in fact a tiny star), Jupiter therefore covered it with its presence and radiance, according to the optical axiom *The greater light obscures the lesser*, as is clearly seen from Ibn al-Haytham, book 1, no. 32, pp. 19–20. 5. That in his figure the stars E and D also appeared to move into K and L, I think was caused by refraction. For since these little stars were then near the horizon, they were subject to no small refraction. Hence, properly speaking, they remained on nearly the same straight line, as can be gathered from Jupiter's motion.

From all these circumstances it becomes manifest that these five little stars, which the Reverend Father counted among the Jovials, were pseudo-Jovials and mere fixed stars. But perhaps someone will object to us that they may have been the Jovials that shone out on August 28 and September 4. I answer that they were by no means among the Jovials: for after that time, in September, October and November, I clearly observed that these five fixed stars remained unmoved in their former place, while Jupiter, retrograde, left them behind it by some inter-

val, which I supply from my own observations. But anyone who refuses to believe this I would ask, in a friendly way, to search out these little stars in the asterism of Aquarius for himself, and without reluctance, with some excellent telescope (for such a one is required for this business): for I have no doubt at all that he will still find all these five in their former place and at the same distance. [Margin: The Urbanoctavian stars of Father Antonius Maria de Rheita are still found in their former place.] For I myself also tried the same thing frequently around the autumn of 1643, after the judgement on the nine new stars had come into my hands, so that the truth of the matter might be established beyond doubt for me, who was then somewhat wavering. And always — not only in 1643, but also in 1644 and 1645 — I found that these five little stars, every one of them, still remained in this sign of the zodiac, Aquarius, at exactly the same distance, just as I represented them in the asterism of Aquarius under figure D. It should be understood, however, that what is required here is an observer practised in directing the telescope at the fixed stars. For since Jupiter is no longer seen near these little stars, they are hard to find, as anyone who has made trial of the matter will readily agree. But one who is less practised will without doubt find them in the end, provided only that he applies due care, as well as all the other 33 that I observed.

6. As for the Reverend Father's belief that his telescope is so excellent and outstanding that these five could not have been seen by anyone else before,

in this too he is mistaken. [Margin: There are other telescopes more excellent than those of the Reverend Antonius Maria de Rheita.] For I too saw them with my telescope before he did, and indeed something more: near the star i (which for him is star b) I saw yet another very small one, marked with the letter m, which he without doubt did not reach with his telescope; otherwise he would have seen ten Jovials, or Urbanoctavian stars — a number, ten, that would perhaps have pleased him more. So there is no reason for him to attribute so much to his Enochian eye, since there are other telescopes too that make objects appear larger still — unless hereafter he brings to light other celestial phenomena, new and previously unknown.

Finally, I am compelled not to deny that someone, in observing the Jovials through the tube, by the neighbouring and surrounding smaller fixed stars [Margin: An unpractised observer is easily deceived by the fixed stars in observing the Jovials.]

could easily be deceived, especially if the observer is still unpractised and a small fixed star appears in the same straight line as the Jovials. This happens very often, and almost the same thing would have happened to me in this celestial spectacle had I not applied more diligent care and observed these little stars once, and again, and again. 1. For in the month of August of the year 1642, when I first began to observe those small stars around Jupiter, I constantly noticed that one of the fixed stars [affixae] already mentioned, namely i, stood in the same straight line with Jupiter, and for that reason at first I even believed it to be one of the Jovials. But as time went on — and in fact on 4 September — I found that Jupiter had left this fixed star more than half a degree behind it, and so I became more certain that it was not a Jovial but a fixed star: for the circumjovials were always carried along with Jupiter. For this reason too, the earlier observations, made before 4 September, are not to be relied on in every respect, because this fixed star mixed itself in among Jupiter's companions; the later ones, however, are so much the more certain. [Margin: How observations of the Jovials should be made so that no one can ever be deceived by the fixed stars.] For having been made more cautious by this mixing of little fixed stars with the Jovials, I learned always to tell the two apart and keep them separate — and new observers will be able to imitate me in this matter, so that they do not, as the saying goes, strike against the same stone and are not deceived by these unknown fixed stars.

Accordingly, I diligently examined with the telescope, day after day, the region of the sky that Jupiter was in the habit of traversing, to find out whether new small fixed stars [Affixae] were also present in it. Whenever I came upon them, I began to note them accurately, in longitude as well as in latitude, and to transfer them to paper. For this could be done more conveniently while Jupiter still fell somewhat further from them than when it came closer to them, since it then greatly obscured them with the brightness of its light. Once this is done, the true Jovial planets can easily be distinguished from the fixed stars,

even when they lie in the same straight line with them, by the difference of observed longitude and latitude, so that in this way a headlong slip need not be feared. It would therefore be worthwhile for all the small fixed stars near the ecliptic that have been observed with the telescope [tubus visorius] to be arranged by longitude and latitude and, once recorded, communicated to the mathematicians.

Therefore, what has been said so far about the nine Jovial stars newly found — as he believes — by the Reverend Father Antonius Maria de Rheita could have sufficed, were it not that the Censure of the most excellent and most learned Don Ioh. Caramuel Lobkovvitzius [Juan Caramuel y Lobkowitz] must also be considered here. He published it very recently, namely in the year 1643, against the judgement of the French Lynx, Father Gassendi, on the nine stars seen around Jupiter. For in this censure the Lobkowitz I have named contends with several arguments against Father Gassendi's Judgement, and with them tries to demonstrate that Father Rheita's five Jovials already mentioned are in truth wanderers [Errones], not fixed stars, and that wanderers of this kind are also found around Saturn and Jupiter. But indeed — to put forward my own opinion on this censure as well, with all respect to so great a man — I think that, on account of the arguments already given and those I shall now add to the earlier ones, he will hereafter agree with me and be firmly persuaded that the five little stars named a little earlier were unknown fixed stars, except one, which the astronomers long ago assigned to the constellation of Aquarius.

[Margin: Examination of Lobkowitz's Censure, set against Gassendi's Judgement.] For as to his first claim, on page 119 of his Censure — that he will demonstrate either that Rheita's observations are unreliable or that the stars observed around Jupiter are wandering stars — we shall weigh the force of this demonstration in the words of his that follow, where he goes on and infers thus: "And since Gassendi neither will nor can establish the former, it is necessary that he concede the latter. To show this plainly" (he adds further) "I shall first set out one or two theorems.

"First: If you consult sight, all the western stars flee a direct planet, and the eastern stars approach it.

"Second: With sight as judge, all the eastern stars and the western stars flee a retrograde planet." So much for him.

As to the first proposition, then, which contains this hypothetical — either Rheita's observations were unreliable or the stars observed around Jupiter are wandering stars — Lobkowitz will easily gather from my reply to the first member of this hypothetical what I think of it. For I would not call Rheita's observations altogether unreliable, since these five little stars are in truth found in the heavens just as the Reverend Father observed them. It does not, however, necessarily follow from this that they

were wanderers around Jupiter. For (as I shall presently show more plainly) these little stars around Jupiter could have been unknown fixed stars, or ones not sufficiently made out by the Reverend Father. This will appear clearly from

an examination of his diagram, once I have proved that the motion of these little stars in the zodiac was merely apparent, not real, and was seen in this way because of Jupiter's own motion, which was at one time direct and at another retrograde.

The two theorems he lays down as his foundation do not go against me; on the contrary, they rather serve to prove my case. To come to the matter itself, then: at the outset I find myself wondering how it happens that Rheita's diagram of the nine stars around Jupiter, as offered to Gassendi, differs in several respects from the one shown to Lobkowitz. Indeed, to say nothing of the difference in the proportion of the circles and eccentrics in the two — though it is no small one — I have thought it necessary above all to point out why, on comparing the two figures, a notable diversity is found in each in the position of these stars with respect to the vertical, or rather to the zodiac, and in the proper motion that they are believed to have completed in their eccentrics between the different observations. Yet every diligent observer applies himself to this alone: to draw his own observations [Τηρήσεις] with the utmost exactness and to communicate them to his friends. For unless this is done, it is generally a sign either that the observation still suffers from some fault or that the observer has left certain things in doubt.

Therefore I shall demonstrate, from a comparison of the two diagrams, that the same thing happened to our observer as well. And so that this can be done more conveniently, I show it unaltered, engraved in copper, in the preceding diagram H, numbers 2 and 3. Now one can see from Gassendi's figure, number 2, that the line of rising and setting as it were intersects the old fourth Jovial planet b. But in Lobkowitz's diagram (as will be clear from his page 85 and page 120, and from number 3 of the preceding figure) that line runs about eleven degrees higher.

Secondly, the vertical line T V in Gassendi's diagram, and in the preceding figure 2, is so placed that it leaves the little star G to the left. But in Lobkowitz's diagram, number 3, it moves the same little star G towards the west [occaſum verſus].

Thirdly, the line X Z in Gassendi's diagram, which passes straight through the three old Jovials, also runs through the little stars E and D. But in Lobkowitz's diagram the line passing through the three ancient circumjovials does not at the same time pass through C C; it bends away below them by nearly thirty degrees. So great a difference therefore seems intolerable, and it does not argue a careful observer: for it follows necessarily that either one or both of the diagrams was drawn up wrongly.

Fourthly, the span of proper motion of the eighth pseudo-Jovial, E K, in Gassendi's diagram, has a position with respect to the seventh, D L, far different from the one it has in Lobkowitz's diagram. Likewise the outermost pseudo-planet F recedes from the vertical line only as far as 17° in the former figure, but in the latter as far as nearly 25°. From this it is abundantly clear that, with so enormous a discrepancy between the two diagrams, the proper motion of

these little stars can by no means be derived exactly, so that greater care on the observer's part is rightly wanted here. But I let this pass, and do not inquire into it scrupulously on this occasion. Since, then, I see that Lobkowitz relies only on the diagram sent to him and pays no attention to Gassendi's, I shall from now on consider that diagram alone, and on its basis take the matter up with Lobkowitz. Before I begin to investigate the motion of these little stars, however, certain obstacles must be removed.

First, then, it is a very remarkable and paradoxical thing that the Reverend Father Antonius M. de Rheita is plainly of the opinion — and would have us believe — that he saw the four old Jovials (otherwise called the Medicean stars), as can be seen from his own diagram set beside Jupiter, and indeed in the following order and position. For three are set on a straight line; but the fourth and last Jovial has here so great a latitude that, if I imagine an eccentric running out from the centre of Jupiter to it, that latitude grows to 15°. [Margin: The position of the Jovials with respect to Jupiter, as regards latitude.] This, however, is contrary to the observation and the opinion of all mathematicians. For these four Jovial wanderers never recede from Jupiter in latitude, whether towards the north [Boream] or towards the south, by more than 3′; indeed, Jupiter Jovialis and Saturn Jovialis, when they are at their greatest elongation from Jupiter (as they stood at this time, as

accurate observation of Gassendi testifies) never admit any latitude at all, as all my observations of the Jovials, to the last one, set out in the Appendix, also confirm. Accordingly, that fourth little star, to which he assigns so great a latitude, was not a genuine Medicean Jovial, nor, as the Reverend Father holds, one of the new Urbanoctavian ones, but beyond doubt a fixed star. Here, however, someone may perhaps object to me the observation of Father Gassendi, who on the same day also noticed four Jovial wanderers. I readily grant, indeed, that all four were seen by Gassendi, but in a different position with respect to Jupiter from the one given by the Reverend Father so often named. For the star nearest to Jupiter stood off from it by only one semidiameter, which does not exceed 1½′ — something to be carefully noted; the second by two and a half diameters; the third by three and three-quarter diameters; the outermost by five and a quarter diameters, as is read in the Judgement, page 23. There he also adds that all four stood in one *straight line*, except that the second star from Jupiter appeared somewhat more to the north, though almost imperceptibly so. This observation shows clearly that by no means so great a latitude belongs to the fourth and last little star as the Reverend Father Rheita represented; rather, it was found lying exactly in one straight line with the third and the first towards Jupiter, so that this little star can in no way be admitted to the number of the four Medicean Jovials, but stood outside their count.

But the reason why the Reverend Father saw only three old Jovials on that day, while Father Gassendi saw all four, is not hidden from me, since I notice that neither of them added the hour of the observation, although both observed on one and the same evening. Hence it came about that the two did not notice

these little stars at one and the same moment and minute of time; rather, one of them made these observations an hour or an hour and a half earlier, the other later. If the observation was made in this way (and I have no doubt of it at all), it may very well have happened that the Reverend Father could not make out the Jovial nearest to Jupiter, which by Gassendi's observation at Paris was only 1½′ away from it. Accordingly, if the Reverend Father set himself to observing somewhat earlier, then this Jovial nearer to Jupiter, which

from conjunction with Jupiter had begun to move, he could not yet perceive by sight; but if he had observed Jupiter later, so that the same Jovial had hastened towards conjunction with Jupiter, he would again have been unable to see it. For it is established with certainty from the observations of the Jovials that the nearer Jovial is the swiftest, and completes its whole period in one day and some hours besides (as was also said above), so that it covers 1½′ of longitude in less than an hour and a half, especially when, being nearer to Jupiter, it advances along a straight line. From this it is easily understood — and I am certain of it — that the Reverend Father did not at that time see with his telescope this smallest Jovial, the one nearest to Jupiter, but only the three remaining, larger companions of Jupiter. And although Father Gassendi saw them somewhat differently as regards their distance, this does not trouble me: for, on account of their motion, it could have happened that at the time of the Reverend Father's observation they stood at an equal distance, and at just such a distance as they are found at in both diagrams. Moreover, the Reverend Father Antonius M. Rheita's observation of the Medicean stars confirms that, in viewing these stars, he either anticipated somewhat or put off somewhat the time at which Gassendi applied himself to observing them. Hence my opinion is all the more firmly established that the fourth Jovial, the one nearer to Jupiter, was not seen by Father Rheita, but only the three remaining larger Jovials, as was also said a little earlier.

That he seized on the fourth little star, which was not without latitude, as a Jovial came about, I think, because the Reverend Father knew that the number of the Medicean Jovials is four; and since at that time this fixed little star was very close to Jupiter, he was led to believe that it was the fourth Jovial wanderer. And this is the first point we have thought worth noting about this observation of the Jovials.

The second is this: at this time the Medicean stars, as Father Gassendi's observation, set out in his Judgement, plainly shows, stood not to the west, as the Father recorded them, but to the east. From this it necessarily follows that the Reverend Father Rheita's optical tube represented these celestial phenomena in an inverted position. This the man most distinguished for his rare learning, Caramuel Lobkowitz, willingly, in his Censure, page 131,

concedes, saying: *"For the Rheita* (that is, the tube) *, although it does not consist of four lenses, nevertheless shows us towers hanging from the sky, and inverts all lines; and so, since the same satellites were seen as western at Cologne and as eastern at Paris, the observations agree, although they seem unable to cohere."* So he writes. Since,

therefore, Rheita's telescope showed all objects inverted, it follows that not only the Medicean stars but all the other new Urbanoctavian stars as well were seen in the same inverted position. I cannot help wondering, then, why Don Lobkowitz was unwilling first to set upright that inverted diagram, which was offered to him the first time, and to put the little stars in their proper positions, before demonstrating the motion of the new pseudo-Jovial little stars. For anyone readily understands from this that if this diagram is kept inverted, as it was communicated, everything that ought to have been eastern would become western, and conversely what was western would turn out eastern. And so it happened that in Lobkowitz's diagram certain little stars appear to have come nearer to Jupiter which ought nonetheless to have been more remote; and conversely, some appear to have receded further which have nonetheless come nearer.

To make this all the better understood, I shall invert Lobkowitz's diagram and make it conform to the natural position of these little stars. No special skill is needed for this: if the lower part of the diagram is turned into the upper, the thing is done. In this way the part that formerly faced the setting now points towards the rising, and what was on the right inclines to the left. And so that no doubt may remain here for the inexperienced, let him, I ask, look at this diagram, at the proper distance, through a lens convex on both sides and made in the manner of a burning-glass; he will at once discover how the diagram ought to be inverted. For it will certainly appear in no other form than the one engraved on copper plate H at number 4, which was also presented by Franciscus Pennemannus, who published Lobkowitz's censure of Gassendi's Judgement, and set at the head of that censure, and which I also inserted in the earlier diagram as number 2.

Now that this diagram has been inverted in this way, and it is established from the demonstration above that the fourth little star, which had latitude,

and which Father Rheita assigned to the Medicean stars, was not in fact one of these little stars, although it was among those he calls the new Urbanoctavian stars. I therefore wish to ask the reader to consider carefully this diagram as inverted by me, or the other one, Gassendi's, number 2, in the proportion and position in which they are placed here. When this has been done, and these figures have been compared with mine, which I engraved from my own observation on copper plate H at number 1, it will become plain from them that the little stars marked with the letters C C in Lobkowitz's diagram, or with the letters E D in Gassendi's, are placed in the same way as C h in my diagram, and that Father Rheita's fourth pseudo-Medicean star is where i is placed in mine; and again, that the star at E in Lobkowitz's diagram and at H in Gassendi's is the one at K in mine. As for the tiny little star m in my diagram, it has nothing to do with those nine Urbanoctavians, since the Reverend Father did not see it with his telescope, as I also mentioned before. And to continue the comparison of these little stars: M in Lobkowitz's diagram, or F in Gassendi's, the one further from Jupiter towards the left, is l in my figure, although in my picture

it lies a little lower. I think this difference arose because the Reverend Father could not trace its true distance from Jupiter so exactly from one observation and another. Moreover, a comparison of his two diagrams shows that in other respects too he did not take so accurate an account of everything: for, as was already demonstrated earlier, he placed certain little stars some degrees higher or lower in the earlier diagram than in the later one.

You will notice, besides, that Father Rheita's last-but-one little star, which C represents in my diagram, was the greatest of these in brightness, because it was one of the old fixed stars, the one called "the following of the two in the first bend of the water", of the fifth magnitude. These five little stars just mentioned are Father Rheita's new Urbanoctavians, as I shall also show a little later from the motion they exhibited.

But someone may perhaps ask here: what, then, is the little star G, which not only Lobkowitz's diagram but also Gassendi's

displays? Let him know that this too is a particular fixed star, which the Reverend Father also observed along with the rest. In the year 1642, indeed, when I was occupied in observing the others, I did not see this one, because I did not look around Jupiter over so wide a circuit. But recently, namely on 1645 November 9, when I was once again examining Rheita's diagram carefully and was again surveying the Urbanoctavian stars in the constellation of Aquarius with my tube, I found that this same little star G was still visible in this sign together with the others, and that it lies almost in a straight line with the stars k and i observed by me, and about half a degree higher. This little star, moreover, is not the smallest of all, but fairly conspicuous; I marked it with the letter n in my diagram number 1. From this it appears that it is the very same star as G in Rheita's diagram.

Accordingly, whoever carefully compares these diagrams of the Urbanoctavian stars with my diagram and with the fixed stars observed by me will, I know, admit that one egg is not so like another as these little stars, drawn in the different diagrams, are like those I observed and marked in a separate diagram, as regards their position — even though I noticed them four months earlier, namely on 1642 August 28 and September 4; for Rheita's observations fall on December 29 of the same year and on January 4 of the following year.

From this it is gathered in the same way that if the stars we observed at different times — and, let me grant even this, in the same position of Jupiter with respect to the ecliptic — had been wandering stars, it would be impossible for our observations [Τηρήσεις] to agree so closely with one another, and for these little stars to have been seen by each of us in the same form, position and distance. For, as all mathematicians know, the Sun does return in a period of one year to the same sign and to the same degree of the zodiac that it held a year before; but over a span of very many years the same concourse and arrangement of the other planets, with respect to the Sun, in latitude as well as in longitude, does not always return. For although one or two may perhaps

have come back to the same place and distance from the Sun, yet the third, the fourth and the rest will by no means

return to the same position with respect to the Sun. The same holds for Jupiter and its Medicean stars. Every year, indeed, Jupiter twice returns to the same place of the ecliptic; yet its companions, the Medicean stars, do not come back to their usual places in a like time, nor keep the same position relative to Jupiter, because they are wanderers and neither move with an equal motion nor are carried round in the same spans of time. And the same thing holds, beyond contradiction, for these new Urbanoctavian stars — or rather new fixed stars, which I may with the best of titles call Vladislavian [ULADISLAVIANAS], since I saw them here during the prosperous reign of Władysław IV, before the Reverend Father did. For if these stars had not been fixed but erratic, it could plainly not have happened that our observations agreed with one another, given the differing motion they would have had on Father Rheita's view. And even if by some chance one or another of the wanderers had stood in the same place, this would still not have happened with the rest; rather, by reason of their position, now this one and now that one would have been missing. But since they did not change their position, it necessarily follows that these stars were fixed stars, which are found to this very hour in the sign of Aquarius (as was also said before), as anyone equipped with a good optical tube may find by experience. Near Jupiter, however, it will no longer be possible to see them until a span of about 12 years has passed from this time, and then only if Jupiter has by then regained the same latitude.

That these little stars seemed to the Reverend Father to move, and indeed quite noticeably, within six days (as is evident from the diagram he presents), is nothing to wonder at, since this apparent motion of the tiny stars necessarily arose from Jupiter's own direct motion and is to be attributed to that alone. So that this may be the better understood, I have tried to sketch in my diagram the motion of each of the stars which we may thus call Vladislavian, in its eccentric, and its apparent progress up to a whole degree, which Jupiter's motion produced; and how they appeared to the Reverend Father on January 4, at Jupiter's second station, in the same way as, in a like position, on August 28, in the year

of the year before, I saw them. This very thing can be seen in figure H, at number 1, where the motion is shown with o in each eccentric.

Come, then, let us compare the motion of these little stars with one another, and see whether their motion offends against Lobkowitz's first and second theorem. In Lobkowitz's inverted diagram, number 4, the outermost star M — the outermost, that is, of the Urbanoctavian stars — has been drawn back to the lower place L; in my figure, number 1, l, the outermost, likewise stands lowered at o. Lobkowitz's sixth wanderer, namely E, has been moved down towards the right to F. In Gassendi's diagram H passed over into I. In the same way, in my diagram the star k has moved further on at o, and i at o — which had likewise to be so, even though Father Rheita did not note its motion, because

he counted this star among the Medicean stars; in truth, however (as was shown before), it is of the same kind as the other Vladislavian stars.

As for the two outermost stars, namely the seventh and the eighth, or next-to-outermost: in his figure they have been made higher and raised up, at D D. But I, attending to Jupiter's own motion, could not perceive that they had changed their places; rather, they remained for the most part on the same straight line. Why they appeared to him in this position I believe arose from a greater refraction. For the rest, that their motion, being derived from Jupiter's own motion, agrees entirely with his motion is abundantly clear from comparing the two; so that, according to the first theorem, those that were due to come nearer to Jupiter, and those too that were due to recede farther from him, had in this way no other motion — except that all were carried towards the west, not towards the east, as Father Rheita and Don Lobkowitz maintain.

And, to put an end to this matter: from what has been said, anyone understands more than well enough that Father Rheita's Urbanoctavian stars are entirely my fixed Vladislavian stars, which are still seen in the same place of the zodiac; and that his observation is not on that account to be called untrustworthy, as the distinguished Lobkowitz, on pa-

Diagram. Engraved plate, Fig. I, signed at the lower right "Aut. Sculpt." (engraved by the author). Its title runs across the head: *Observations of fixed stars around Saturn, Mars and Jupiter, made at Danzig in the year of Christ 1644.* Below the title the plate is ruled into twelve panels in four rows. Each panel shows the planet at its centre or near it — Saturn as a ringed ellipse, Mars and Jupiter as plain circles — among six-pointed stars of graded size, with small engraved numerals set beside some of the stars. The numerals are given below as engraved, without interpretation.

- Row 1, left panel (no number or planet symbol over it): "September 29, at 10^{h} in the evening". Saturn with stars above and below it; numerals 45, 20, 40, 30, 15, 15.
- Row 1, right panel (no number or planet symbol over it): "September 30, at 5^{h} in the morning". Saturn with stars above and below it; numerals 30, 20, 60, 25, 20, 15.
- Row 2, panel "3. ♄": "November 19, at 9^{h} 45^{m} in the evening". Saturn with stars to its left and below; numerals [?]0 (first digit 7 or 4), 10, 20. A diagonal rule cuts off the lower left corner of this panel.
- Row 2, panel "4. ♄": "November 22, at 9^{h} 45^{m} in the evening". Saturn with two stars below left; numerals 15, 20.
- Row 2, panel "5. ♄": "November 26, at 8^{h} in the evening". Saturn with three stars; numerals 19, 20, 20.
- Row 3, panel "1. ♂": "September 16, at 2^{h} in the morning". Mars with stars to the left and below; numerals 16, 60.
- Row 3, panel "2. ♂": "September 30, at 5^{h} 30^{m} in the morning". Mars with three stars below; no numerals.

- Row 3, panel "3. ♂": "November 19, at 9^h 45^m". Mars with one star above right; numeral 16.
- Row 3, panel "4. ♂": "November 20, at 11^h". Mars with one star directly above; numeral 3.
- Row 3, panel "5. ♂": "November 22, at 7^h in the morning". Mars with one star above left; numeral 15.
- Row 4, panel "1. ♃": "In the year 1643, November 2, at 9^h 30^m". Jupiter among scattered stars; numerals 10, 20, 24, 30, 45.
- Row 4, panel "2. ♃": "In the year 1644, September 30, at 5^h in the morning". Jupiter among scattered stars; numerals 15, 30, [?], 15, 50 [?] (the first figure is 5; the "0" is not settled — it may be a small raised o-form, i.e. a degree sign, rather than a figure on the line), 25.
- Lower left: "Fig. I."; lower right: "Aut. Sculpt."

ge 119, seeks to infer; for those new stars remain, and Rheita's observation deserves the praise due to it.

[Margin: Both Rheita's circumsaturnal and his circummartial stars were fixed.]

For the rest, as far as the circumsaturnal and circummartial stars are concerned, there is no doubt that they were no less fixed than those that were seen attending Jupiter. Indeed, I have learned well enough from continuous observations over several years that this is not infrequent but happens quite often. For at no time — however diligently and however often I examined and studied Saturn and Mars with telescopes of no ordinary kind — could I find around them wanderers of their own, except those two little handles on either side of Saturn; and if anyone wishes to call these wanderers, he may do so with my leave. This at least is certain: with my optical tubes I have frequently detected unknown fixed stars of various magnitudes, sometimes more, sometimes fewer, around Saturn and Mars as well as around Jupiter. I shall prove this by some observations entered in Figure I.

[Margin: First observation of Saturn.]

In the year 1644, on September 29, at 10^h in the evening, I noticed six little stars around *Saturn*. How far each was from the next, or from Saturn itself, is shown by the numbers, which indicate minutes of a degree; for I always recorded that separation anxiously and carefully, as far as it could be done. [Margin: Second observation of Saturn.] In the second observation of Saturn I noticed more of them, so that they reached the number ten. [Margin: Observation 3.] In the third observation, however, only three of them were visible. [Margin: Observation 4] In the fourth only two appeared. [Margin: Observation 5] And in the fifth observation three were present again. I could bring forward more observations of this kind if there were need; but for the sake of brevity I hasten to those that were seen around Mars and the remaining planets. [Margin: Observations of Mars.] For whenever I turned the spyglass on the star of Mars and watched it closely, I also found various stars around it, as is plain from the five accompanying observations of Mars; and from the third,

fourth and fifth observations it becomes evident that Mars was then retrograde. [Margin: Observations of Jupiter.] In the same way I sometimes found seven around Jupiter, as these two observations confirm, besides the four Medicean stars, which lie in a straight line. The kind reader will find many more such examples in the Appendix of Jovial observations.

And let this much be said, briefly, about the new Pseudo-Jovial stars of the Reverend Father Antonius de Rheita, and also about the things in the star of Jupiter that deserve notice.

[Margin: Method of taking the distance of the circumjovial stars from Jupiter itself.]

It remains for us to set out in a few words the method of taking, with the telescope, the distances of the circumjovial stars and of the neighbouring fixed stars from Jupiter. Before us, that most eminent mathematician Galileo used to do this: he first investigated the compass of the optical tube, and from it he afterwards deduced the distances of the stars. That was certainly not badly done. This way, however, is far more certain: the diameter of Jupiter is also measured through the telescope, and one then notes by how many diameters of Jupiter this or that Jovial wanderer is removed from Jupiter itself. For this can be done without any difficulty, because the lesser Jovials are separated from one another by only a little. Hence, if the observer of the heavens reduces the aperture of the optical instrument to the length of Jupiter's diameter, and makes it his practice to gauge the intervals of Jupiter's satellites against this distance, he will not easily go astray in finding the digression of the circumjovial stars. Next, from this arrangement of the tube one also sees without effort when they stand in a straight line and have the same latitude, and which Jovial wanderers are in conjunction or form a triangle. Finally, constant diligence and practice in observing Jupiter's companion stars in this way through the optical tube will make anyone far more certain, and will not allow him to be in doubt about the true distance.

[Margin: Observations of the star of Mars, and description of a telescope by which its genuine face may be detected.]

1. As for the star of MARS: it too lacks light of its own, as do all the other planets and the circumjovials; for it borrows that light from the Sun on the side turned towards us, while on the other side, turned away, it is dark and casts a conical shadow from itself. 2. Next, it too always acknowledges the Sun as its centre. Hence it comes about that at one time it is nearer the Earth than at another, especially when Mars is acronychal — that is, when it stands in opposition to the Sun — so that it is then nearly seven times nearer to us than when it is in conjunction with the Sun; and for that reason it also appears far larger.
2. Moreover, I am fully convinced that this planet, as an opaque body, undergoes changes in its light, like Ve-

nus, Mercury and the Moon — yet in such a way that it can never be seen horn-shaped [Corniculatus] or sickle-shaped [Falcatus], as the other inferior

planets are; rather, it takes on a dichotomous [Greek: διχότομον (dichotomon, "cut in two")], or bisected, phase when it is perigee and stands in quadrature with the Sun, just as Kepler also states in the *Epitome Astronomiae Copernicanae*, page 843. For with an excellent telescope I found that this opinion is not only probable but also agrees with experience itself: in the year 1645, on March 26 at seven in the evening, and likewise on the 28th of the same month, when Mars appeared for the most part halved, just as I drew its phase in the preceding figure G, at D.

[Margin: The author observed Mars halved.]

4. Furthermore, the appearance this planet presented when the nobleman Fontana viewed it through a tube is known from the treatise of Matthias Hirschgarter: for Fontana saw it as an uneven, rough mountain, tapering to a point, and by no means round. If such a face of the star of Mars were really to be seen, it would certainly be singularly wonderful and astonishing. But, my kind reader, I shall set out for you the truer form of the star of Mars.

[Margin: In what form Mars was observed by Fontana.]

I do not deny, indeed, that if I view this planet through the same kind of optical tube with which I contemplate the Moon, Jupiter and Saturn, Mars presents nearly the same figure that I reported from Matth. Hirschgarter's treatise. But it must be understood that telescopes set up in this way are less suited to recognizing the genuine appearance of the star of Mars. For unless the superfluous light that abounds in Mars is taken away, the planet will appear not round but spun out into a point, and girdled by a ruddy circle as if by a rainbow.

[Margin: The usual telescopes are of very little use for observations of Mars.]

When, however, you prepare for yourself an optical tube of the kind I described in the third chapter, so that the fixed stars are seen round, and you narrow the hole in the paper placed against the convex glass, then you will indeed find that Fontana was deceived by the adventitious light of Mars, and did not use a telescope suited to keeping it out. For Mars, carefully inspected in this way, will appear in no other than a spherical figure, which one may view clearly, distinctly and evidently by this method — something that cannot be done with the usual telescopes. Hence the others, not furnished with this aid to the visual instrument, have never seen Mars round and without rays. For that

[Margin: The body of Mars is round.]

reason they have never been able to see Mars on the wane. But if you fit up your optical tube in the manner described above — especially if it is long enough, perfectly made, and furnished with excellent lenses — then you will be able to see Mars dichotomous when it is bisected.

[Margin: On the star of Venus and of Mercury.]

As regards the star of VENUS and that of MERCURY, the mathematicians of our time have written more about each of them, including things not observed before, than the ancients did. For not only do they look to the Sun as their

centre and circle it, now above it, now below it; they also wax and wane in their light like the Moon, and go through all their phases. This the old astronomers neither noticed nor handed down.

[Margin: The faces of Venus.]

1. Venus is seen full of light and round when it is western and direct and has made its conjunction with the Sun in the apogee or aphelion. When it advances a little further, it becomes gibbous; and when it reaches its greatest elongation from the Sun (which never exceeds 47°), it is seen halved through the telescope. But when it is retrograde and hastens towards the other conjunction, in the perihelion and below the Sun, it wanes more and more in its light, so that at last it appears sickle-shaped and horn-shaped, until it runs into the rays of the Sun and is hidden by them. Again, when in the morning, after conjunction with the Sun, it emerges from the Sun's rays and begins to become eastern and matutine, it is seen through the optical tube first sickle-shaped; then, at greatest elongation, bisected; and finally, on its return to the Sun and a little before its immersion in the Sun's rays, it is again found round and full with the telescope.

Anyone equipped with an optical tube of good quality can make trial of this varied appearance of the star of Venus; for this outstanding celestial spectacle deserves both the careful gaze of the eyes and the exact contemplation of the mind. For my own part, I candidly confess that I have very often viewed these different faces of Venus, not without singular pleasure of mind and eye. Therefore I cannot help recalling the figure it presented in the year of Christ 1644, in the month of September. For when, before sunrise, it began

to present itself to be seen, I attended carefully to each and every one of its phases. And I am firmly convinced (let this be said without boasting) that these observations of Venus have not been published or made known before; for I noted them with the greatest care not only in the hours before dawn and before sunrise, but also by day, with the Sun very bright and very high, through a telescope skilfully made, furnished with excellent lenses and neatly arranged.

[Margin: Daytime observations of Venus.]

For this reason I shall not only set before your eyes here all these phases of Venus, each and every one as I observed it, engraved in copper for the benefit of lovers of mathematics and of the stars; I shall also explain here everything about each phase that deserves notice. For I have no doubt at all that from these appearances of Venus, well perceived and carefully explored by me, some things about Venus that were less well known before can be drawn out. I found, namely, that the phases of Venus can be noted better and more surely by day, with the Sun bright, than by night; that a small hole applied to the convex lens of the spyglass [Perſpicilli] reveals the face of Venus more than a large one does, and what the difference between the two is; and that Venus can be seen by day with the naked eye not only at its greatest elongation from

the Sun, but sometimes also shortly after its first emergence from the rays of Phoebus — and other things of that kind, which will follow.

I now come, therefore, to the observations themselves. In the year 1644, on September 30 (New Style), at $5\frac{1}{2}^{h}$ in the morning before sunrise — the fifth day after its morning emergence, but the twelfth after its conjunction with the Sun — I first began to view the face of Venus with my optical tube, of the kind with which I usually observe Jupiter, the Moon and Saturn at other times. Its radiance appeared very slender and scarcely equalled the size of an inch and a half, and its horns looked very sharp, though its diameter was seen to be fairly large. This spectacle of Venus was outstanding and not unworthy of being seen; it is shown in the present diagram K, number 1. The face of Venus appeared no larger than that of a New Moon of two or at most three days. With the same face also on the following day, namely October 1, and with the same size, whether through a large or through a very small hole,

[Margin: First observation of Venus.]

applied to the convex glass, it was seen. Its diameter appeared fairly large — indeed larger by a quarter than the diameter of Jupiter. Here, however, it should be noted that in the present diagram I deliberately did not make one of its diameters larger than another, even though around the first observations Venus appeared larger than afterwards: for just as Venus diminished in diameter, so it grew in light. For just as no infallible, evident and certain account of the decrease and increase of the diameter has so far been found and clearly demonstrated, so too no necessity compels us here to enlarge or contract its diameter. I therefore decided to keep it equal in every part, because all our observations investigated not the variation of Venus's diameter but the diversity of its phases.

[Margin: Second observation of Venus.]

2. On October 13, at 6^{h} in the morning, before sunrise, I observed Phosphorus again; to the naked eye it indeed appeared larger than on September 30. And through the telescope too, fitted with a larger as well as with a smaller hole, its phase exceeded a size of four digits. At 7^{h}, after sunrise, I again viewed Venus in the east, not only without the telescope but also with my eye armed with the telescope. There its phase appeared one inch smaller than at 6^{h}, and I also found its horns far sharper than before sunrise. At 8^{h} I could still see Venus with the naked eyes, although it was now fairly small. But when I inspected it through the tube, it had not fallen off in diameter: for I now observed the same diameter that I had noted at 6^{h}. The phase, however, not only appeared more distinct, and its horns sharper; it was itself also more contracted and thinner in its circuit, so that I could not estimate it as larger than $2\frac{1}{2}$ digits. Around 9^{h} it had not yet escaped my sight, although it was seen to be fairly small. But around 10^{h}, having gradually grown dimmer, it had vanished. As for its true diameter, comparing this observation with the one I had made

on September 30, it was by now plainly diminished. It should therefore be noted here that Venus, although it did not exceed a size of 2½ digits, by day, with the Sun fairly high, not only with the naked eyes but also with the spyglass excellently

Diagram. Engraved plate, signed "Fig. K." at the lower left and "Aut. Sculpſ." [engraved by the author] at the lower right, under the title *Observations of Venus by Day, made in the year 1644*. Twenty-five discs of equal size stand in five rows of five. Each disc is drawn as a circle with its dark part hatched and its lit part left white, and carries a planetary sign. Nineteen discs carry the sign of Venus (♀) and are numbered 1–19; six carry the sign of Mercury (☿) and are numbered 1–6. In the first three rows (Venus 1–15) the lit part grows from a thin crescent on the left (1) through a half-disc (8) to a gibbous disc (11–13), to a full white disc (14); disc 15 is lit on the right only. The fourth row and the first disc of the fifth row are the Mercury discs: on 1–2 the lit part is on the left, on 3 about half the disc is lit, and on 4–6 the lit part lies on the right. The last four discs of the fifth row (Venus 16–19) show thin crescents lit on the right, narrowing from 16 to 19. The engraved labels, in order (m. = morning, v. = evening):

- Venus 1 (top row, first): "Die [[3/8]]0 Sept. hor. 5[?] m." — September 30, at 5½^{h} in the morning [?]
- Venus 2: "Die 13 Octob. hor. 8. m." — October 13, at 8^{h} in the morning
- Venus 3: "Die 20 Octob. hor. 8. m." — October 20, at 8^{h} in the morning
- Venus 4: "Die 30 Octob. hor. 8. m." — October 30, at 8^{h} in the morning
- Venus 5: "Die 6 Nov. hor. 9. m." — November 6, at 9^{h} in the morning
- Venus 6 (second row, first): "Die 1[[1/5]] Novemb. hor. 10. m." — November 15, at 10^{h} in the morning
- Venus 7: "Die 21 Nov. hor. 10. m." — November 21, at 10^{h} in the morning
- Venus 8: "Die 25 Nov. hor. 9. m." — November 25, at 9^{h} in the morning
- Venus 9: "Die 30 Nov. hor. 10. m." — November 30, at 10^{h} in the morning
- Venus 10: "Die 2 Decemb. hor. 9. m" — December 2, at 9^{h} in the morning
- Venus 11 (third row, first): "Die 11 Dec. hor. 10 m." — December 11, at 10^{h} in the morning
- Venus 12: "Die 17 Dec. hor. 9 m." — December 17, at 9^{h} in the morning
- Venus 13: "Die 13 Januar. hor. 9. m" — January 13, at 9^{h} in the morning
- Venus 14: "A^{o}. 1645 Menſe Octob. v." — 1645, in the month of October, in the evening
- Venus 15: "A^{o}. 1646 20 Mart. hor. 7. v." — 1646 March 20, at 7^{h} in the evening
- Mercury 1 (fourth row, first): "Die 22 Nov. hor. 7. m." — November 22, at 7^{h} in the morning

- Mercury 2: "Die 30 Nov. hor. 7. m." — November 30, at 7^h in the morning
- Mercury 3: "Die 2 Dec. hor. 7. m." — December 2, at 7^h in the morning
- Mercury 4: "Die 16 Maij. hor. 8½ v." — May 16, at $8½^h$ in the evening
- Mercury 5: "Die 20 Maij. hor. 9. v." — May 20, at 9^h in the evening
- Mercury 6 (fifth row, first): "Die 30 Maij. hor. 9½. v." — May 30, at $9½^h$ in the evening
- Venus 16: "A°. 46, 3 April. hor. 7. v." — [16]46 April 3, at 7^h in the evening
- Venus 17: "A°. 46, 8 April. hor. 7. v." — [16]46 April 8, at 7^h in the evening
- Venus 18: "A° 46, 14 April. hor. 7. v." — [16]46 April 14, at 7^h in the evening
- Venus 19: "A°. 46, 21 April. hor. 7½. v." — [16]46 April 21, at $7½^h$ in the evening

Blank verso of the plate leaf; the plate shows through in mirror image.

could be viewed. This had previously been little noticed, while many believed that it could not be seen by day until it had become bisected and stood at its greatest elongation from the Sun.

[Margin: Third observation of Venus.]

3. On October 20, at 7^h, around sunrise, I again observed the phase of Venus, larger than about four digits. At 8^h, however, with the Sun higher, I noted with the help of the telescope that it was not larger than three digits, as can be seen in the appended diagram, number 3.

[Margin: Fourth observation.]

4. On October 30, before sunrise, Lucifer shone out quite large. Viewed through the tube, its diameter equalled about 5½ digits. After sunrise, however, seen with the armed eye, it scarcely exceeded 3½ digits. See phase number 4.

[Margin: Fifth observation.]

5. On November 6 and 9 I again observed Venus in the east while the Sun was shining, and found its diameter equal to 4½ digits. On this very day, moreover, I saw it clear and bright, with the telescope and without it, not only around 8^h in the morning but also around 9^h, 10^h and 11^h. And I believe it could have been seen by me for longer, perhaps for the whole day, if I had been able, amid my occupations, to keep watching. Shortly before noon, around 11^h, I always found Venus more sharply pointed, clean and clear, so that I can by no means assert, as others before me have done, that Venus then presents horns that are not sharp but blunt. It can also be noted here that if the diameter of Venus reaches five digits, or about that, and it is inspected through the usual hole, either before or at sunrise, it appears not round but angular and unevenly rayed. But when

I apply a small hole, I see it in a round and tapering form. On November 11 it still stood at almost the same size.

[Margin: Sixth observation.]

6. On November 15, at 10^h before noon, its diameter did not quite reach five digits.

[Margin: Seventh observation.]

7. On November 21, before sunrise, its diameter seemed to exceed six digits. But by 10^h it was seen to be no larger than 5½ digits. Its true diameter, however, was not so great around this time, since it was not much larger than Jupiter's.

[Margin: Eighth observation.]

8. On November 25 and 28, at 9^h and 10^h before noon, I saw Venus exactly bisected, like the Moon when it stands in quadrature with the Sun. Before sunrise, to be sure, it seemed somewhat gibbous, with a size of nearly seven digits. But the light densely spread around it made it larger than usual, as had often happened before as well. Here again it should be observed that although phases of this kind appear in Venus by day, with the Sun very high and bright, it is not enough to strip the adventitious rays from Venus with the common, large hole placed on the upper rim of the convex lens; it is better, even by day, to use a smaller hole. This I experienced most clearly at this time.

[Margin: Ninth observation.]

9. On November 30, around 9^h and 10^h before noon, Venus appeared somewhat gibbous, so that the line of section of light and shadow had begun to be no longer straight, as is set before the eyes in the earlier figure, number 9.

[Margin: Tenth observation.]

10. On December 2 and 4, at 9^h in the morning, I was again compelled to place a small hole on the far glass of the viewing tube, so as to make out Venus stripped of the adventitious rays, and its phase, clearly and distinctly. And necessity drove me to do the same on the following days. On this day its luminous part fell not much short of seven digits.

[Margin: Eleventh observation.]

11. On December 11 and 13, at 9^h in the morning, an eighth digit had also been added to the previous size.

[Margin: Twelfth observation.]

12. On December 17, at 9^h in the morning, its light appeared spread out to as much as nine digits, or about that.

[Margin: Thirteenth observation.]

13. On 1645 January 13, with the Sun fairly high, Venus had spread its radiance widely over more than ten digits.

From this time on, as dark weather set in and other occupations intervened, I was no longer able either to see or to observe Venus. Now, however, I shall add some conclusions drawn from these observations.

[Margin: Venus at perigee, viewed with the naked eyes, appears quite small.]

I. That Venus as a morning star, viewed with the naked eyes, often does not present so large an appearance, especially when it is nearer to conjunction with the Sun and is in its perigee, where its phase is still small, even though its diameter and its whole body are then the largest of all.

[Margin: Venus: the farther it recedes from the Sun, the more its light grows.]

II. The farther Venus recedes from conjunction with the Sun, the greater its light appears, although its diameter decreases.

[Margin: Venus appears largest to the naked sight when its phase does not exceed five or six digits.]

III. Its radiance, however, presents itself to the eyes at its very greatest when it reaches a size of five or six digits. After that it falls off in light from day to day, just as it had grown before, until conjunction with the Sun, so that this axiom can be applied to it: the more Venus grows in light, the smaller its diameter becomes, and the smaller it appears.

[Margin: Venus: the more it grows in light, the more it decreases in respect of size.]

IV. In the hours before dawn and in the morning Venus always shines out larger. By day, however, with the Sun set high, it is perceived as narrower by the naked sight; yet when it is inspected with the tube, its diameter is found not to differ on account of the time.

[Margin: Venus appears larger before sunrise.]

V. With the aid of the telescope one may view Venus distinctly and clearly, even if its light does not yet exceed two digits in size, through a large as well as through a small hole, and before as well as after sunrise.

[Margin: Horned Venus is seen equally clearly through a large and through a small hole.]

VI. As soon as Venus is seen with its light increased, however, it is examined more conveniently before sunrise with a small hole applied; and the earlier in the morning it is, the smaller the hole needed. After sunrise, on the other hand, a large hole can do the same.

[Margin: What is to be observed when its light has increased?]

[Margin: When should a smaller hole be used?]

VII. But when it equals five digits, a smaller hole must always be placed on the tube, both before and after sunrise, and by day. For the more it grows in light and the fuller its phase becomes, the smaller the hole that must be used, if it is to appear to us not unevenly flaming and angular, but genuine, distinct and globular.

[Margin: Evening observations of Venus.]

Finally, before we come to Mercury, let us likewise add some observations of the evening Venus as it decreased, made after sunset. From these phases the decrease of Venus will be just as clearly evident as its increase became known from the preceding ones.

[Margin: Observation 1]

14. In the year 1645, in the months of October and November, a little after its evening emergence, it shone with its disc almost full.

[Margin: Observation 2]

15. In the following year, 1646, on March 20, at 7^h in the evening,

Venus had decreased very greatly in its light, so that I found its diameter scarcely exceeding 5 digits.

[Margin: Observation 3]

16. On April 3, at 7^h in the evening, its bright part equalled about three digits.

[Margin: Observation 4]

17. On April 8, at 7^h in the evening, the phase of Venus seemed scarcely to exceed two digits, and it shone with sharp horns.

[Margin: Observation 5]

18. On April 14, at 7^h in the evening, its light scarcely had the size of an inch and a half. Its appearance, moreover, was almost like that of the first crescent phase, observed in the year 1644 on September 30 in the morning.

[Margin: Observation 6]

19. On April 21 the horn-shaped phase of Venus did not exceed the size of one digit; indeed, I scarcely remember ever having observed so very thin a face.

[Margin: Observations of Mercury.]

Here I shall also add some observations of MERCURY, which I hope will not be unwelcome, since they are usually very rare. For in aphelion Mercury does not recede more than 28° from the Sun, and in perihelion not more than 18°. It is therefore seen less often, even when it stands at its greatest elongation from the Sun, because of the long twilight, morning or evening, in which it often lies hidden — so much so that few are found who have examined the increases and decreases of its light exactly with the telescope, or have recorded its phases.

[Margin: Why has it not been possible until now to observe the changes [?] of Mercury?]

The reason, beyond doubt, was chiefly this: that they always kept the same, equally wide hole on the convex lens. For once I had on occasion put on a narrower hole to suit the position of Mercury, and had surveyed Mercury in this way, I was then able to make out its phase clearly and distinctly; and in the same way anyone hereafter equipped with a good and long viewing tube will be able to notice these changes of light in Mercury.

[Margin: And to examine the phases of Mercury a narrower hole must be used.]

[Margin: Observation of Mercury 1.]

1. The first observation of Mercury that I made — the one I have drawn, engraved in copper, in the first place — was in the year of Christ 1644, on November 22 new style, at 7^h in the morning. For I examined it with a good spyglass and found it still little diminished in light, and its diameter small, indeed smaller than the diameter of Mars, as far as I could gather from a comparison with the diameter of Venus, so that it did not yet amount to 1½′.

[Margin: Observation of Mercury 2.]

2. On November 30, at the same hour, 7 in the morning, I again examined Mercury carefully with the telescope and observed that it appeared not yet bisected, but gibbous; although I believe that at this time it was not larger than halved. That its phase nevertheless appeared somewhat larger to me arises from this: even with a small hole applied, we cannot yet entirely remove its superfluous light. For it is established from the observation of Venus that not even with a tiny hole can we strip it of all the light poured around it, unless this is done after the rising of the bright Sun, and in clear daylight. But since this cannot be done with Mercury — because its diameter is smaller, it stands very close to the Sun, and it is not seen by day — it comes about that its phases can appear one or even one and a half digits larger than they really are. Hence I am fully of the opinion that for this reason the diameter of Mercury always appears larger, and that it can therefore be reckoned correspondingly smaller.

[Margin: Why do the phases of Mercury appear to us somewhat larger than they really are?]

[Margin: Observation of Mercury 3.]

3. On December 2, at $7^h\ 15^m$ in the morning, the phase appeared smaller than bisected, as is evident from figure no. 3. To the naked eye it was smaller, but surveyed with the telescope it seemed larger than before. With the astronomical radius [Radius Astronomicus] I also took the distance of Mercury from Spica, which I found to be 30° 45′; and likewise its interval from Venus, which was 26° 55′; and also the separation of Venus from Spica, which was 6° 46′.

[Margin: Observation of Mercury 4.]

4. In the year 1645, on May 16, at $8½^h$ in the evening, I again observed Mercury, which appeared not yet halved, as is evident from its diagram number 4. Its diameter appeared larger than when it was a morning star, and also somewhat larger than a fixed star of the first magnitude, when I viewed it with a small hole applied to the convex glass. On May 18, at 9^h in the evening, it stood out not much different from its former shape.

[Margin: Observation of Mercury 5.]

5. On May 19 and 20, at 9½^{h} in the evening, it showed itself almost halved. On May 23 and 24 it offered itself to view in nearly the same way.

[Margin: Observation of Mercury 6.]

6. On May 30, at 9½^{h} in the evening, I again observed Mercury, and noted it nearly bisected; on which occasion I also, at the same

time noticed that the new horns of the Moon were present, past the fifth day after new moon [interlunium]. Its phase is shown in the preceding figure, as number six.

CAPUT V.

Chapter V.

On the great and wonderful light of the Sun, its spots and faculae, and on their nature; how they can be observed by a different, new and easy method; and also on the things to be considered in observing them.

[Margin: The works of God are immense, wonderful and countless.]

When we set before ourselves for consideration the works of God in this world, whether in heaven or on earth — of which we nevertheless see and know only the smallest part, while far more lie hidden from us and are more numerous than we could recount, as King and Prophet DAVID records (Psalm 40, verse 6) — then we are compelled, with Ecclesiasticus, the excellent herald of the Wisdom of GOD, to break out into these words: *Lord, how wonderful and desirable are your works; who can be sated with seeing your glory? It is conspicuous in the immeasurable height, in the pure expanse of the firmament.* Above all, however, the Sun at its appearing proclaims the glorious GOD; of which the wise Doctor Ecclesiasticus, already named a little earlier, speaks thus in chapter 43, verse 2 and following:

[Margin: Praise of the Sun from Ecclesiasticus.]

The Sun, rising, announces the day; it is a wonderful instrument, the work of the Most High. When it is at midday it parches the land; and who can stand against its heat? It blows into the furnace with the works of its heat. Threefold the Sun burns the mountains, breathes out fiery vapours, and, shining with its rays, dulls the eyes. Great is the Lord who made it, and by his words he has stilled its course!

[Margin: The Sun was made on the fourth day, from the primeval light.]

It is fitting, and rightly so, to consider this most splendid Phoebean lamp of the world, as the most eminent work of GOD, with closer attention, and to describe it with a somewhat fuller pen. Here, at the outset, we do not oppose those theologians who teach that that first light, created by GOD out of nothing, was transferred into the body of the Sun on the fourth day of creation. Indeed, it seems not to contradict the text of Moses that the first-born Light was of the same nature as the Sun, since then too, from the motion and

revolution of that Light, both the morning and the evening hours, day and night, could be told apart from each other. The one thing that light still lacked was that on the fourth day it should at last receive from GOD its own particular

appearance, form and place in the heavens. Whether this primeval Light was a clear and shining light or a fiery cloud, I shall not now dispute. For my part, I believe it can be proved, both from the testimony of Holy Scripture and by evident reasons, that the Sun is a true and real fire.

[Margin: The Sun is a true and material fire.]

But since this matter has already been treated quite fully enough by Christoph Scheiner in the *Rosa Ursina*, book 4, part 2; by Franciscus Patritius [Francesco Patrizi] in the nineteenth book of the *Pancosmia*, page 108; and by Father Franciscus Reita à Talleacotio in his *Meteorologia*, book 1, *On Fiery Meteors*, chapter 10, I send the kind reader to them to read, so as not to do what has already been done.

Meanwhile this much is certain: this prince of the stars, the Sun, is spherical in itself, as its rotation [circumactus ejus in orbem] clearly shows. It is not, however, exactly polished and smooth on its surface like a convex mirror, much less composed throughout of parts alike and of a single kind. Rather, it consists of parts of many forms and of different kinds; and these distinct parts not only have unequal light at different times, but also have their own distinct motion, consisting in a certain variety and continual flux, so that it varies to some degree from day to day. Hence clear traces of generation and corruption appear in the Sun.

[Margin: The Sun is spherical, somewhat rough on its surface, and made up of heterogeneous parts.]

[Margin: Traces of alteration and corruption are detected in the Sun.]

To the Aristotelians, no doubt, this statement will seem far too harsh and altogether intolerable. Yet if they are lovers of truth and do not wish to go blind at midday, they will allow it to be shown to them by evident arguments that the spots [Maculae], small lights [luculae] and faculae seen on the Sun, primary as well as secondary, by no means arise from a deception of sight (as they all too often chant at us on this point), but are true and genuine phenomena and the very representation of the object. For since the burden of proof lies on the one who affirms, I shall, for the sake of defending the truth, prove that very point by indubitable reasons in reviewing my observations of the sunspots [Macularum Solarium], so that no one, unless he suffers from an itch to contradict, can rightly oppose it.

Just as these faculae, spots and shadows, then, wonderfully vary the outward appearance of the Sun, so also in the body of the Sun

they form distinct colours, some of which also come from the very light of the Sun, so that the Sun always appears clearer and brighter towards its centre and middle, while the further that light extends towards the periphery, the weaker and darker it becomes; and this colour is not unlike the flame of fire.

[Margin: The Sun is a compact body, in Kepler's opinion.]

As to the nature of the particular matter of the Sun, of which this body consists, the most skilful mathematician Kepler writes and holds as follows in the *Astronomiae Pars Optica*, page 225, and in chapter 34 of *De Motu Martis*,

page 176: *The body of the Sun consists of matter the densest of all, of the whole world; and within its very narrow sphere as much matter is enclosed as is dispersed in the whole ethereal air through the almost infinite extent of the solid sphere of the world. That the density of this body is of the highest degree is demanded by its heating power, so keen and reaching so far. For among burning things of the same quantity, each burns the more violently and the farther, the denser it is: a coal more than a flame, red-hot iron more than a coal.* Therefore, since in Kepler's opinion the Sun is so dense a body, it can for that reason emit its light all the more strongly.

[Margin: The Sun is to some degree pliant and spongy.]

Others, however, with Raphael Aversa [Raffaele Aversa], hold the contrary, namely that the nature of the Sun is liquid; and so Aristarchus of Samos, in his *System of the World* [Systema Mundi], lately published at Paris, page 23, believes *that the Sun is not altogether hard, like crystal or stone or some such body whose parts cannot be bent, but to some degree pliant and spongy, with a rough, harsh and uneven surface, strewn all over with mountains and valleys; and that it likewise teems on every side, inside and out, with many mountains and cavities, as if with fibres and veins, like a sponge or the lung of some animal.*

Although this opinion does not seem to me so absurd, I nevertheless leave everyone free to judge it, and I wish that both views may be weighed carefully and the arguments compared, since so abstruse a matter is thoroughly worthy of further consideration. For I am fully convinced that in the whole universe there is nothing greater, nothing joined with greater wonder, than the light of the Sun, which it spreads from itself into the whole world and also projects towards the earth circularly and pyramidally. This happens in the following way.

[Margin: How the Sun spreads its light onto the earth.]

I. The light of the Sun is indeed propagated along straight lines; but this is not to be understood simply. Rather, it is so that this visible body of the Sun shoots out to any point of the earth a cone of illumination, whose base is the visible circle of the Sun and whose vertex is any illuminated point.

[Margin: The Sun shoots out its rays in three ways.]

II. Since this earth of ours is surrounded by a vaporous region, the rays of the Sun therefore advance in three ways: direct, refracted and reflected. Hence it comes about that the operations of the solar rays are so diverse, and that at one time and in one place the Sun heats something more, at another less. Its action, however, is strongest with direct rays, because these fall on the surface of the earth without any hindrance. Next, it also acts through refracted rays; and although these are weaker, they too are stronger in one place than in another, according as the rays of the Sun strike the vaporous sphere more obliquely or more directly, and as that sphere is denser or rarer, deeper or thinner. In this way the solar rays are enfeebled and, as it were, dulled. Finally the Sun also acts through reflected rays, which are extremely weak; and so the Sun's action through these too is rendered very weak. For it happens, when the Sun is below the horizon, that its rays and light glide down into the opposite part of

the hemisphere; by them the stars above the horizon are lit at night, and from there we receive the light of the Sun poured back onto the earth, and feel the weakest light of all and a very slight heat of the Sun.

[Margin: The solution of some difficult questions depends on the threefold projection of the Sun's rays.]

Whoever correctly grasps this threefold action of the Sun on these lower things through a threefold ray will be able without difficulty to comprehend, understand and solve many pleasing questions, geographical and optical as well as astronomical. Such are: 1. Why does the Sun heat the earth more in summer than in winter, although around midwinter [brumam] it is nearer to the earth than around the summer solstice? 2. Why does the rising and setting Sun bring in less heat than around midday? 3. Why are the Sun's rays that come onto a wall or into a valley more effective than if they glide onto a plain? 4. Why is it that the Sun heats less in places where the pole is higher than where it is lower? 5. What is the cause that people who lie beneath the perpendicular incidence of the Sun's rays feel the greatest heat? And there are other questions of this kind, which we pass over in silence because they are foreign to our purpose.

It remains for me to touch also on some points concerning the Sun's place, size and distance from the earth, as also its motion and its monthly rotation.

[Margin: The Sun occupies the centre of the world.]

As for the Sun's place, I side with the opinion of those who hold that this most ample, most brilliant and most useful radiance [jubar] — which not only lights the whole globe of the earth with its rays but also warms and sustains all creatures with its heat — was set by almighty GOD, at the very beginning of creation, in a place from which, as from a midpoint, it could cast its rays equally towards all the extremities: namely, in the very centre of the world. For many distinguished astronomers have proved, by evident reasons and certain demonstrations, that no other place in the body of the universe befits the Sun; so that in our own time the most skilled masters of the science of the stars agree with this opinion. The Peripatetics alone set out to attack this doctrine with all their might. Their reason is that, if this theorem stands, the Earth must necessarily be moved out of the centre of the world, against the opinion of Aristotle, all of whose precepts they consider most solid — so much so that they hold it a sin to depart from them even by a nail's breadth. This is all the more so since the Sun's position at the centre of the world presupposes and establishes the motion of the Earth and, conversely (as they wrongly infer), the rest of the Sun at the centre of the world.

[Margin: The Sun, though it stands at the centre of the world, is moved.]

But the rest of the Sun does not follow at once, by any necessary reasoning of the mathematicians, from the Sun's position at the centre of the world. For the more recent astronomers assert a daily revolution of the earth about its own axis, and an annual motion according to the order of the signs through the twelve signs of the ecliptic — a twofold conversion which others, with Ptolemy, ascribe to the Sun and the primum mobile. Even so, they do not deny the Sun

all motion; they assert instead that the Sun turns about its own centre, so that it completes one conversion about its axis in 27 days or thereabouts, that is, thirteen times within the space of a year, from east to west with respect to the apparent motion.

[Margin: The Sun completes its periodic motion about its axis in about 27 days.]

Meanwhile, however, the motion is according to the order of the signs, just as the planets move in their epicycles. Hence the Sun does not always keep the same face, as the Moon does, but changes it daily — something first noticed not so many years ago. Today this motion can be shown openly to anyone from the variation of the spots on the Sun's disc, and put before the eyes beyond doubt. This motion does indeed take place about the Sun's axis, but in such a way that its poles do not remain fixed in one place, but are turned about in the space of a year:

for at daily and monthly intervals they are carried forward more and more from the western quarter into the eastern.

[Margin: The Sun has two movable poles.]

There are two poles, the southern and the northern, and in whatever way the one moves, the other moves likewise. But the one always advances in the visible hemisphere, the other in the opposite part.

[Margin: How are the poles moved?]

The pole that faces the apparent hemisphere is carried from west to east; the opposite one proceeds with the contrary motion, so that if the one rises, the other, conversely, sets. And this motion is always uniform and regular; from it the curvilinear and rectilinear motion of the spots follows of necessity, as will be shown more fully in what follows.

[Margin: How great is the Sun's distance from the Earth?]

Finally, concerning the Sun's distance from the Earth, and its size, the following should be held. The distance is not always equal with respect to the Earth. For at the greatest elongation, with the earth standing, as it were, at aphelion, the Sun is removed from us by 1182 semidiameters of the Earth, which make 1,016,520 German miles. When it is at perihelion, however, it is 1101 semidiameters of the earth away, which make 946,860 German miles. Kepler, admittedly, makes this distance of the Sun from the earth far greater, extending it to 3469 semidiameters of the Earth, as appears from his *Copernican Astronomy* [i.e. the *Epitome Astronomiae Copernicanae*], book 4, page 490.

[Margin: The size of the Sun.]

According to the hypotheses of Tycho Brahe, the Sun is 140 times larger than the Earth, so that its diameter equals 8944 German miles. According to Kepler, however, the Sun's diameter is 15 parts, of which the Earth's is one. We therefore rightly marvel at the stupendous size of the Sun, its immense distance from the earth and its singular motion, and with the King and Prophet David we exclaim, from Psalm 104, verse 24: *How magnified are your works, O Lord! You have made all things in wisdom; the earth is filled with your possession!* And

again, from Psalm 103, verse 22: *Bless the Lord, all his works, in every place of his dominion.*

But enough about the most brilliant radiance of the Sun, which the son of Sirach (chapter 43, verse 2) most beautifully calls an instrument, or a marvellous vessel. It remains for me, however, to treat — briefly, yet clearly and distinctly — the spots and faculae visible on the surface of the Sun, and their true constitution, generation, dissipation and motion, both rectilinear and curvilinear: in such a way that I establish this motion by observations that are not in the least doubtful, and also disclose the method of observing, with every preparation and precaution.

[Margin: On the spots of the Sun, after Galileo, no one wrote earlier or more brilliantly than Christoph Scheiner.]

And indeed the spots and faculae of the Sun appear as quite wonderful phenomena, above all to those who have never seen them before, since many singular and unheard-of things besides occur in connection with them. They certainly ought to be counted among entirely new discoveries, since they were detected only a few years ago, with the help of the optical tube, by Galileo, that most eminent Italian philosopher. At about the same time, it is true, Christoph Scheiner, a man of incomparable and all-embracing learning, was very much occupied in observing these same spots. In the observations he later published he showed such diligence that he can be said to have, as it were, snatched the palm from everyone in this field; and he earnestly urges all astronomers whatever not to fail, taking their example from him, to turn eye and mind to these phenomena — so recent and wholly unknown to the ancients — with the very greatest diligence. Since, then, he has gone before us so laudably in this matter, leaving no stone unturned in observing these spots for the benefit of posterity, so as to investigate their nature and their true motion as accurately as possible — considering that an exact knowledge of this solar phenomenon would bring a notable benefit not to astronomy alone but also to the whole of natural philosophy — it is surely right that we follow in his footsteps and, as far as we can, inquire into all these things likewise with the greatest zeal. What the author just mentioned achieved can be seen splendidly in his excellent work, which he entitled *Rosa Ursina, sive Sol* and published in the year of Christ 1630.

[Margin: The usefulness of observing the spots.]

Indeed it certainly cannot be denied that, once the nature of the solar spots is rightly understood, something beyond doubt can be established about not a few controversies in physics and astronomy, and those far from trivial. For the Peripatetics above all will at last understand, from the rise and decay of these spots, that the doctrine of generation and corruption in the heaven is not an empty figment of the brain and some imaginary appearance, but is drawn from the very nature of the heaven and is really founded in the aether. The astronomers, for their part, will demonstrate more than sufficiently, from the observed course of the Sun's spots, the Sun's monthly conversion on its axis

about movable poles, and will also most evidently confirm their opinion of a fluid heaven [cœlo liquido],

and they will also learn from this to deduce the difference in the longitudes of places, broadly speaking, between different and more distant cities, and other things of this kind. Since, however, this could not be explored and known at once from few observations, nor could the nature, matter and motion of alteration of the spots be investigated so quickly, Scheiner, the man praised above, was obliged to devote the labour and care of many years to the matter. His aim was to put forward something certain about the spots of the Sun and to prove by invincible reasons that they do not arise from a deception of sight and imagination, or from some human fiction (as some rather foolishly hold), but are really in the Sun, revolve with it, and are essential phenomena of the heaven.

[Margin: The author too undertook observations of the spots.]

For these and other reasons I too was moved, out of love of truth, to record these spots of the Sun in exact observations throughout a whole four years. These observations confirmed beyond any doubt every one of Scheiner's remarks on the spots of the Sun, and taught me that new spots are constantly generated and destroyed on the Sun's surface; that they have their own annual and monthly motion and astronomical and physical risings and settings; and that they undergo all the other changes which the often-praised Scheiner detected. For I conducted these observations with the greatest diligence and with the apparatus of a good telescope and of the other instruments, and for that reason I have also inserted them into the Appendix to the *Selenographia*. Indeed, they serve above all this purpose: that everyone may compare his own observations with them, learn from them the uniform motion of these irregular spots and so understand it better, and know for certain that the spots are without any parallax, as Galileo and Scheiner had also noticed before in various places. They serve, further, to make it clear to him that these spots are on the surface of the Sun, and that they are neither shadows cast onto the Sun by other bodies, nor to be valued so highly as to be taken for stars — as Iohannes Tardè [Jean Tarde] and Carolus Malapertius [Charles Malapert] made them, the Bourbon and the Austrian Stars [Sidera Borbonia, & Auſtriaca]. For he will see plainly and perceive that the following can be asserted about the spots of the Sun.

[Margin: That the spots are soot driven out of the mass of the Sun by the force of heat.]

1. That the spots contained in the disc of the Sun are nothing other than some compacted and dark

matter, not unlike our earthly clouds, and movable together with the Sun.

[Margin: That the faculae are the brighter part of the Sun.]

2. That the faculae mixed among them are the brightest parts of the Sun, which are seen on the Sun more and more at distinct places and times.

[Margin: What are the properties of the shadows?]

3. That those shadows which follow the body of the faculae and are mingled with the little lights [luculis] vary on the surface of the Sun in rarity, shape and size, like smoke and mist; and that the Sun, overcast with them here and there, appears sullied like a mirror by a touch or by the breath of the mouth. And although they are not as durable as the spots, they are nevertheless seen on the Sun from time to time, either mixed with faculae or alone, and soon afterwards are dispersed again and vanish.

Since, however, we have come upon this subject of the spots and faculae of the Sun, let no one hold it against us that we are somewhat lengthier here in treating it, so as to make it a little clearer.

[Margin: How many kinds of solar spots are there?]

For it should be understood that the spots of the Sun are of two kinds: some primary [Primarias], others secondary [Secundarias]. The former are again of two kinds, either larger or smaller; and these in turn are either simple, or compound, that is, mixed. Those are called simple which have no faculae mixed in with them. These, again, are either whole, and present a shape that is in some way regular; or they are ragged, and cannot be reduced to any ordinary shapes.

Compound and mixed spots are those which either cohere closely in a series that is not continuous but interrupted, or consist of faculae and spots together. Among these, simple and compound alike, of either species, still further differences occur: for some are denser, others rarer. The denser are those that consist of more compacted matter, and so commonly last longer on the Sun before they are extinguished.

[Margin: The density and blackness of the nuclei is greater than in the other parts of the spots.]

2. Next, there are also some which appear with a very compact nucleus, and with matter that is quite black and denser than the remaining parts of the spot.

[Margin: The behaviour of the rarer spots.]

The rarer spots, on the other hand, have no nucleus at all, and yet they sometimes last just as long as the spots endowed with a nucleus, so that they traverse the whole diameter of the Sun. These are not of one form throughout, but now darker, now lighter.

[Margin: Some spots, especially the larger ones, glow reddish.]

3. In the same way other spots appear, especially those that are larger, of a pale, saffron colour, like a halo (of the kind that, round the Moon,

is usually seen) — tinged with that colour. In the smaller spots a colour of this kind is rarely noticed.

[Margin: Example of a large spot crowned by a saffron halo.]

A notable example of this kind could be seen in 1642 October; it is shown in the 1st figure at H H, where a larger spot, which had a double nucleus, was surrounded by a yellow halo and persisted until the spot's exit from the disc of the Sun. That rarely happens, for spots mostly arise in the middle of the Sun.

4. Some spots are also called sterile, because they lack nuclei and are uniform in colour and matter. You will find such a spot, seen in 1642 June, in the 4th figure at L L.
5. There are, besides, other spots which, although they appear in the ordinary way at once at their rising near the Sun's horizon, nevertheless do not remain the same, but either grow or diminish; if, however, they always keep the same size, they are said to remain in the same state. A growing spot of this kind occurs in the 5th figure at M M, in 1643 June and July, marked with the letter f; and in August of the same year in the 9th figure, in the cluster of spots e. Far more spots, however, are found diminishing, especially in the 10th figure at Q Q, seen in 1643 September and marked with the letters c, d and e.

[Margin: Why are spots thinner at the edges of the Sun than in the middle?]

But a spot persisting at the same size can be seen in the 1st figure at H H, which I observed in 1642 October. At its entry, it is true, this spot, like all the others, appears somewhat thinner than in the middle of the Sun. This is not because it really was thinner, but because it is common to all the spots of the Sun to be attenuated near the edges and periphery of the Sun and to grow larger in the middle. For near the edges they are seen under a more acute angle of vision than in the middle, since in this way it is not their true length but their breadth and, so to speak, their depth that the eye perceives — by force of the optical rule: *All things seen under a greater angle are seen greater, and those under a smaller angle smaller.* (Witelo, book 4, theorem 20; Ibn al-Haytham [Alhaf.], book 47, nos. 40, 41, 42; Maurolycus, book 1.)

[Margin: Some spots are not seen and generated at once on the very horizon of the Sun.]

6. Moreover, very many spots are observed which do not, in the ordinary way, run onto the Sun right at their rising, but come into being and are generated now on the nearer, now on the farther surface of the Sun, now in its eastern part, now in the western, now in the middle. Some of these remain constant, and sometimes even grow, right up to the setting

of the Sun; some, however, cease to exist before they reach the western horizon, so that they arise on one day — and that in the middle of the Sun — and perish again on another, as can be seen from the 3rd figure at K K and from the eastern spot c, seen in May.

[Margin: Which spots are called returning?]

And yet, among other spots of this kind, there are also some — very rare, it is true — compacted of so durable and tenacious a material that they cross the visible hemisphere of the Sun not once only but a second time as well. These spots are called *returning* [reduces]: such was the one seen in 1643 July and shown in the 6th figure as spot a, as it is accurately described there. Frequently, too, two spots equal to each other are seen on the disc of the Sun at one time, so entirely alike in matter, size, consistency and colour that the observer judges they will either set or perish at a like time. But this happens rarely: for one

of them vanishes some days sooner than the other, before the observer had expected — and that is remarkable.

[Margin: 7th kind of spots.]

7. Many spots, too, surrounded by many faculae and shadows, first appear at the eastern margin of the Sun; the faculae and the shadows withdraw after a day or two, while the spot remains intact and unchanged; and again, before the spots go out of the Sun, at its western edge, they commonly return, so that just as these spots arrived crowded with faculae, so too they go out of the Sun again not without them. A notable example occurs in the 9th figure at Q Q, in 1643 August, where at first bare faculae appeared; from these, on the following day, six small spots were born, which varied wonderfully over the following days. The faculae, however, soon failed on the third day, and did not shine again until about the time the spot left the Sun. Of the same kind, too, was the spot a shown in the 6th figure and observed in 1643 July. Sometimes also a spot arises on the Sun without faculae and afterwards withdraws from the Sun accompanied by faculae; such a one is shown in the 8th figure, noticed in 1643 August.

[Margin: 8th kind of spots.]

8. Some spots on the Sun are born from shadows, and within a few days suddenly grow, enlarge and thicken; but

a little later, sooner than expected, they dissolve into shadows before they are carried below the western horizon, so that what is commonly said as a proverb happens to them: what comes quickly, quickly perishes.

[Margin: 9. The remarkable behaviour of the faculae.]

9. As for the faculae, they too are not of one kind: some shine with a more brilliant light, some with a weaker; some are endowed with a somewhat yellow colour; others enjoy a pure and whitish light. The bright faculae, moreover, always stand out more brilliantly above all the rest of the Sun's light, so that this light always flashes out above the rest of the Sun's radiance.

[Margin: The distinction of the faculae.]

Such faculae, again, are of two kinds. Some are found more stable and durable, so that when they appear at the Sun's rising horizon they do not scatter, but remain until they hide themselves in the western part of the Sun and vanish. Although this happens very rarely, you will nevertheless find an example of it in the 10th figure at RR, under the letter a, observed by me in 1643 September. And although that facula varied from day to day, it nevertheless persisted on the Sun and went out again at the western limb. The rest, by contrast, are less stable, and remain only about the Sun's horizon, for two or three days; afterwards, if they advance further, they are extinguished in the middle of the Sun or pass into spots. Here this too should be noted: as long as these faculae cling within the Sun's embrace, they undergo various changes from day to day more frequently than the spots; moreover, when the faculae are mixed with shadows, they spread out more widely, so far that they sometimes

occupy a quarter, sometimes a third, of the Sun's diameter. Such great and very widely spread faculae and shadows — beyond what anyone, perhaps, would believe — occur in the 7th figure at OO; I saw them on 1643 July 20.

[Margin: The size of certain spots and faculae.]

How many German miles these faculae equalled, anyone can measure from the known size of the Sun's diameter. For if the diameter of the Sun is taken as 8944 German miles, then these faculae were 2981 German miles long and 994 miles wide — a length and breadth monstrous to tell, in comparison with our Earth. For the length of these spots is much greater than the length of Europe, Asia and Africa, which runs only to 2700 miles, so that these faculae exceed the whole size of all three parts of the world by 300 miles; and their breadth comprises a space

which stretches from the Mediterranean Sea to the Cape of Good Hope.

[Margin: The spots of the Sun are not phantasms but real bodies, whose size takes in several German miles.]

10. But, to return to the spots, there is no reason for anyone to persuade himself that they are deceptive appearances and empty tricks of the senses. For they are in truth corporeal substances, consisting of the three dimensions of length, breadth and depth, although this last is hard to investigate. Once the ratio of the spot to the diameter of the Sun has been established, its length is found. For example: if a spot stands as 1 to 24, it is then 384 German miles long. You will find such a spot in the 4th figure at L L, under the letter b, on 1643 June 18. Sometimes, however, they are larger, so much so that they equal Africa in length.

[Margin: Why are the spots much larger than they appear?]

Indeed, even the smallest, which appears only as a point, exceeds a German mile in length. Although this size may seem incredible, these spots are in themselves much larger still than they appear. For since the Sun is far larger than the body of the spots itself, it illuminates their far side beyond the half; hence a spot looks smaller than it really is. This follows the demonstration of the opticians, and especially of Ibn al-Haytham, *On Twilight* [de Crepuſculis], no. 3, who says: *If a luminous sphere illuminates a smaller opaque body, it will illuminate more than a hemisphere.* See also Witelo, book 2 of the *Optics*, theorem 27.

[Margin: The spots are generated only in a certain part of the Sun.]

11. Moreover, it is also necessary to know that the primary spots are not generated in every place on the Sun, but hold their own particular seat in the middle of the Sun's disc. There they form, as it were, their own zodiac: they rise and perish in it and complete their course.

[Margin: How great is the latitude of the spots towards either side of the Sun's ecliptic?]

This zodiac, however, is much wider than that of the planets in the heavens, for it extends to 40°, 50°, and indeed sometimes even to 60°, so that on either side of the ecliptic this space runs out to 30°.

[Margin: Why are only secondary spots, shadows and slender faculae found around the poles?]

Around the poles no large spots are seen, but only secondary shadows and sometimes small faculae. The cause of this does not seem hard to investigate. For since the condensation and rarefaction of the spots proceed from the rotation and motion of the Sun, it can happen that, because that motion is far more vigorous in the middle of the Sun, more frequent and larger spots can be generated in that part; conversely, since the Sun's motion around

the poles is slower, for that reason such very dense bodies cannot exist in those parts; there only secondary spots, shadows and small lights are found.

[Margin: The spots have fixed limits.]

12. Within these bounds, which form as it were their own zodiac, the primary spots always carry out their motion. This motion is threefold: local; of generation and corruption; and of rarefaction and condensation. The last two motions were dealt with briefly above, where we also said something about the spots' increase and decrease, and likewise about their rarefaction and extension. It remains for us to set out something about the local motion of the spots as well, which is itself threefold.

[Margin: The local motion of the spots is threefold.]

[Margin: The first comes about with the Sun's daily motion.]

The first is produced by the Sun's daily motion (if the Sun is taken to be moving in the ecliptic), by means of which the spots are carried together from east to west.

[Margin: The second, through the Sun's motion of ascent and descent, or of the angle of the ecliptic and the vertical.]

The second arises from the Sun's daily motion of ascent and descent, which the vertical line encloses together with the line of the ecliptic converging on the Sun's centre. For every day, by its daily motion, the Sun ascends in the forenoon and descends in the afternoon; hence the angle between the ecliptic and the vertical at the Sun changes from moment to moment, because of the varying elevation of the ecliptic and its inclination to the vertical circle — and noticeably so, even within an hour. For this reason, too, the spots do not appear always to sit in one and the same place on the Sun. There is indeed some difficulty in rightly understanding and investigating this angle; yet the angle that the ecliptic makes with the vertical circle at the Sun's place can also be found and demonstrated mechanically on a globe.

[Margin: The third motion of the spots is their own, from the eastern edge of the Sun to the western.]

The third motion of the spots is their own and natural one. It always begins in the eastern part of the Sun and ends in the western, and the spots complete it within 12, 13, or at most 14 days, according as they have a greater or smaller latitude. This motion, however, is not uniform on every day of the year, nor are the spots carried along the same line in their zodiac: their motion is for the most part curved, but more winding at one time than at another. And although

at first sight this motion seems to be joined with the greatest irregularity, in itself it is only a kind of anomalous uniformity, while

their main path is more or less curved. For within one half-year this winding course bends towards the south; within the other half-year it tends towards the north. And the spots carry out this motion every year in an unchanging manner. For although one spot sometimes vanishes in the middle of the Sun's disc and another is born, that new spot too keeps the same position and motion at any time, and does not depart from it, except that its declination from the ecliptic varies somewhat. But to make that obscure motion clearer, I shall try to explain it more plainly still.

[Margin: A fuller explanation of the motion of the solar spots.]

These spots, while they move clinging to the surface of the Sun, traverse each day a twelfth part of the Sun's diameter as they advance from east to west, as was already said above in explaining the threefold motion. This course is made either in a straight motion or in a curved one. It is straight only twice a year. The first time is around the beginning of December, when the spots cross the Sun in a straight position, and this straight motion lasts 14 days or thereabouts. After that they make their course more and more winding, so that the convex part of the arc inclines towards the north-east [Arctopelioten] and the concave part towards the south-west [NotoZephyrum]. This lasts for a space of three months, in December, January and February. Then comes their vernal equilibrium, when, at an equal distance inclined to the ecliptic, they stand equally far from the east [Euro] and the west [Zephyro] — for this happens at no other time. In the following three months, namely March, April and May, they so adjust their pace that their convex obliquity tends towards the north-west [Corum] and the concave towards the south-east [Euroauſtrum], yet it diminishes and decreases little by little, so that at the beginning of June they begin once more to proceed in a straight line. Soon they change their oblique course in the opposite way, so that in the months of June, July and August the convexity tends towards the south-east [Notapelioten] and the concavity towards the north-west. Then follows the autumnal equilibrium. In the last three months the course of the spots is bent back again: the convex part slants towards the south-west and the concave towards the north-east, yet in such a way that around December it becomes straight again. And this continual reversal and alternation of the motion arises, properly speaking, from the annual motion of the Sun's poles, as I also pointed out a little earlier.

[Margin: The motion of the Sun's spots is unequal in appearance, but in reality equal and uniform.]

13. Further, as to the daily distance that the spots cover on the Sun's surface, it should be understood that, although their motion is uniform and equal, it nevertheless has an appearance of unevenness and inequality, especially near the Sun's horizons, where the distance is always narrower than in the middle. For the nearer a spot is to the periphery, the smaller the distance becomes; the closer it comes to the centre, the greater it turns out. Since

the body of the Sun has been made perfectly spherical, so that nothing could be rounder, it necessarily follows that all the daily distances (as also the Sun's spots themselves) appear thinner when they are nearer the circumference, and look larger when they are further from it and nearer the middle: the former are seen under a smaller angle of vision, the latter under a larger.

[Margin: Things seen under a smaller angle of vision appear smaller; under a larger angle, larger.]

For that optical axiom is perfectly true: *Things seen under a larger angle also appear larger.* Nevertheless, when the spots stand at an equal distance from the east and the west, they then also keep an equal daily distance, as has been clearly established from all the observations made each day at the same hour.

[Margin: From the Aristotelian definition of generation and corruption it is proved that the heaven is corruptible.]

From everything set out above it is clear that the annual motion of the spots is certain and constant, but that their matter is very inconstant and mutable. If a Peripatetic should choose to fight against this with every argument and attack our view, I would beg him again and again not to be reluctant to recite the definition of generation and corruption set out in Aristotle's *Physics*. For I have no doubt that he will produce this one: *Generation is a motion or change from not-being to being. Corruption, however, is a change from being to not-being.* If this assumed definition of generation and corruption is correct, as it certainly is, then it proves most clearly that alterations and alternations of generation and corruption exist in the heavens.

[Margin: Sometimes the Sun is free of primary spots for one, two or three months.]

For although the Sun sometimes appears entirely clean and empty of primary spots for the space of a month, and indeed even of two and three months (as I have observed before now), you will nevertheless often quite soon notice spots of all sorts — now smaller, now larger, now ordinary, now extraordinary — that have arisen on the Sun's disc. Now I ask you, my Peripatetic, tell me: may one not affirm that in the arising of these spots

a change has taken place, from not-being to being? Indeed, unless you wish to contradict the undoubted testimony of your own eyes, you too will declare as follows. A spot which crosses the visible hemisphere of the Sun and never returns; likewise very faint spots born from a single dense one; and again a large spot that has arisen out of many smaller ones; or spots arising from faculae, or shadows from spots, or faculae from shadows — some larger, some smaller, some thicker, some thinner, indeed at times so large that they equal a third of the Sun's diameter and could cover a hemisphere of the Earth with their size, yet failing a little later and sinking away to nothing: this you would call a change from being to not-being.

[Margin: Spots, faculae and shadows that come into being on the Sun and vanish again make it plain that generation and corruption occur on the Sun.]

For my part, my Peripatetic, I can gather and affirm nothing else from all this than that there is greater alteration on the Sun than here on the Earth.

[Margin: Alteration is greater on the Sun than with us on the Earth.]

But you hard-headed ones from the Peripatetic flock are perhaps not yet brought by this firsthand sight [Greek: αὐτοψία (autopsia, "seeing with one's own eyes")] to subscribe to this view. Rather, I believe, you will object that these appearances may be deceptive and mere illusions of sight, or that those phenomena of the spots and faculae exist in the air and not in the aether. To those antagonists, however — to spare time and paper — I put forward by way of reply only the following four reasons, for them to refute.

[Margin: Four evident reasons show that the spots and faculae can exist neither in the aerial region nor outside the body of the Sun.]

1. No sublunary body can carry out a motion as supremely regular as the one the spots continually keep.
2. If the faculae subsisted and moved far below the Sun, they would certainly often appear outside the Sun's disc. But this never happens, as is clear from plain observations.
3. If these faculae were not genuine parts of the Sun, but something distinct outside them, it would follow that a light more lucid and clearer than that of the Sun itself could exist in the nature of things (since the faculae are in themselves far more splendid, as was shown above). But this is repugnant not only to reason but also to Sacred Scripture itself. For Ecclesiasticus, chapter 43, verse 17, says: *that the light of the Sun is the most brilliant of all.* Indeed, since no clearer and no brighter light than the Sun's can exist, it follows that the faculae are genuine parts of the Sun.
4. Moreover, if these phenomena shone upon us from the aerial region, then a notable parallax both of longitude and

of altitude would arise. For even if they were located above the Moon, they would nonetheless have a parallax of a whole degree. But since they are free of all parallax, as is evident from all the observations recorded at the same time in various places, even the most remote, in India as well as in Germany: for everyone noticed that they lack parallax. For when the Sun appears unblemished to us, that is, without spots, it is seen so in every region of the whole Earth as well. From this it is concluded most firmly that these spots and faculae are not only higher than the Moon, Mercury and Venus, but are as high as the Sun itself — indeed, that they cannot be torn away from the Sun itself — on account of the reasons already given, and by force of the astronomical axiom: *The smaller the parallax with which an ethereal body is endowed, the higher it is carried; and the greater the parallax it is found to have, the nearer it is to the Earth.* No philosopher, not even Aristotle himself, will be able to refute this demonstration, for it is utterly invincible and most evident.

Although the reasons I have adduced stand on a firm footing, I nevertheless fear that I shall not achieve anything with them among the Peripatetics. For they pursue with a more than Vatinian hatred all those who demonstrate generation

and corruption in the heaven, as well as those who bring arguments of this kind into the open. So great is the force of this preconceived opinion — that the heaven is free of all generation and corruption — that it does outright violence to the truth. I therefore almost despair of being able to overturn that opinion.

[Margin: Great is the force of an inveterate opinion.]

I would indeed more readily believe that Aristotle himself, if he returned to life, would come over to our view more willingly than his disciples, and would grant all the arguments brought forward. For beyond doubt he inferred the incorruptibility of the heaven from the fact that neither he himself nor all the other philosophers before him had noticed anything notable in the heaven from which they could establish a generation and corruption of the heaven. That foundation stood until the contrary was proved. But now, since it has been shown by certain demonstrations and by testimonies in no way deceptive — and today it can be confirmed and demonstrated by the evidence of the eyes, which is in no way fraudulent or counterfeit, and grasped as it were by hand in the dark — that there exist in the heavens such great and so many

alterations, as great and as many as are not found on our terrestrial globe, we are therefore compelled to affirm with every assurance *that the heaven is subject to alterations.* Therefore, if today we were to set the spots and faculae on the Sun before the eyes of Aristotle come back to life, and show them to him clearly, I would not doubt that so great a philosopher, with his most penetrating intellect, as a devotee of truth and an enemy of deceit, would at once abandon his former view, go over wholly to ours, and vigorously defend it from then on. His followers, however (how astonishing and incredible!), philosophize in a way quite different from their teacher and leader, who used to say, nobly and laudably: Plato is a friend, Socrates is a friend, but truth is a greater friend. For they lay down the incorruptibility of the heaven only because their master Aristotle so laid it down, said it and wrote it. And they value this argument from Aristotle's authority more highly than all the reasons, observations and evident demonstrations to the contrary. But what this proof of the Peripatetics is, of what kind and of what weight, any friend of truth easily sees.

I could indeed pursue and assert this motion of the spots at greater length. But since that is not my primary purpose, and since, besides, it has already been treated quite abundantly by Father C. Scheiner in his published *Rosa Ursina*, I advise the kind reader who is eager to know more about this matter to consult that author. Whatever I have written so far about these phenomena of the Sun, however, I found to be true, taught not by other people's observations but by my own — and those as accurate as could be achieved, and very numerous. From them I have inserted some into my *Selenographia* for the benefit of lovers of astronomy, so that they may better illustrate what I may perhaps seem, out of a desire for brevity, to have said obscurely.

[Margin: Method of observing the spots.]

As to the order of observing the spots, I strove here to follow wholly in Scheiner's footsteps.

[Margin: 1.]

1. Accordingly I took care to enclose within a circle the daily motion and progress of every spot and facula for as long as it remained on the Sun's disc, and also, at times, to display within one and the same circular diagram the complete periods of two different spots, somewhat apart from each other and distinct.

[Margin: 2.]

2. A line drawn through the centre

marks the ecliptic of the Sun. A, towards the left, is the eastern margin, which the spots enter first; B, towards the right, is the western limb, which the spots touch last as they leave. And these are the two horizons of the Sun, namely A and B.

[Margin: 3.]

3. Each particular spot is marked separately with its own letters of the alphabet. The numbers denote the day on which the spots were observed. To the small table attached, moreover, is entrusted the time in hours and minutes at which the observation was made: an appended m signifies time before noon, and u time after noon. The angle of the ecliptic and the vertical is also given there at the same time. The time, however, was taken not from the altitude of the Sun, as Scheiner mostly did in his work, but from a sundial [Sciatherico horologio] divided into hours and minutes. For this method is both easier and not so prone to error as the other, provided the meridian line is securely established and the division into hours has been correctly made — that is, for a definite elevation of the pole; the other method, by contrast, can give the inexperienced and the careless occasion to go wrong in many ways.

[Margin: 4.]

4. The faculae and spots represented in the figures were observed from day to day, as the clearness of the sky allowed. Moreover, their size, proportion and distance were diligently determined, as were their colour, density, nuclei, shadows and related features, so that everything bearing on the explanation of their form and motion was noted with the greatest care and engraved in copper.

[Margin: 5.]

5. What further occurred daily in observing them; how they varied their shape in wonderful ways; what diurnal and annual motion they had; and whatever else about them is worth noting — all this you will see clearly from the attached notes and from their description, and understand far better, if you examine all the inserted figures properly and make the observations familiar to yourself. Finally, with these things thus known beforehand, certain pleasant questions can also be solved without difficulty.

[Margin: Resolution of the questions.]

[Margin: Whether the spots are stars?]

I. Whether the spots should be called stars, which perform their own motion around the Sun and keep it constantly and always? For what answer should be given to this question is evident, and not obscurely, from the observations. That they cannot be stars is gathered from the following. First, the spots almost never appear

round, whereas stars always do. Second, if they were stars, they would not undergo such remarkable changes, nor would they be seen now larger, now smaller; they would keep the same form. Third, they would have to return every day and at all times, and never vanish. But this does not happen. It is therefore rightly inferred that the spots are not stars.

[Margin: Question 2.]

II. Whether the spots that grow blacker commonly grow and increase, while those that grow whiter, by contrast, decrease and diminish? The answer is that this is so.

[Margin: Question 3.]

III. Whether the faculae for the most part follow the spots rather than precede them; or whether they extend themselves more towards the east [Eurum] than towards the west [Zephyrum]?

[Margin: Question 4.]

IV. Whether, when a facula shines forth, a spot is for the most part accustomed to follow upon it? I answer: the observations do not contradict this.

[Margin: Question 5.]

V. The observations also testify that the spots do not revolve about their own centre, but always turn the same face towards us.

[Margin: Question 6.]

VI. Whether the spots that pass into faculae do not, for the most part, become larger than they were before? The observations teach that this question too is to be answered in the affirmative, without any doubt. Several other small questions of this kind, about the condition of the spots and faculae, can also be decided from these observations once they are rightly perceived and grasped; I leave them to the perspicacity of the kind reader to bring out and determine. For something still remains to be said about the method of observing these spots and faculae, and to this I now turn.

[Margin: Several ways of observing the spots of the Sun.]

These can in fact be noted in various ways, as Scheiner mentions in book 3 of the *Rosa Ursina*, page 151.

[Margin: 1.]

1. First, these spots — especially the larger and more conspicuous ones — can be seen with the free and naked eye in the Sun when it is rising or setting, or also when it is somewhat obstructed by misty vapours.

[Margin: 2.]

2. When a mirror with an even and flat surface is so fitted that only a small circular hole lies open in it, and it is set against the rays of the Sun, then

the mirror itself, too, quite evidently the spots and faculae of the Sun on a somewhat more distant (at

20 or more feet from the mirror) wall or white board will display; for the reflected ray of the Sun, penetrating clearly that far, can accomplish this.

[Margin: 3.]

3. If the rays of the Sun, passed through a narrow, round hole into a dark chamber, fall on a white board held up before them, then the image of the Sun with its spots will also come into view — provided the place is dark on every side, and a suitable interval, of fifteen or even twenty feet, lies between the board and the hole. Otherwise, unless these conditions are observed, little or nothing of the Sun's spots will be seen.

[Margin: 4.]

4. When two coloured glasses are taken, a leaf of rather white paper pierced with a very fine needle is inserted between them, and they are glued together with wax or bitumen, then the spots too (as also eclipses of the Sun) can be observed without injury to the sight — especially when no other aids are at hand.

[Margin: 5.]

5. But a far better method of observing is by a helioscope directed at the Sun. How it is to be prepared, however, I explained above, in the second chapter.

[Margin: 6.]

6. Nor should the method be passed over in which a ray of the Sun is admitted into a dark chamber through a single convex glass enclosed in a hole (preferably a movable one). But if the distance between the glass and the board opposite is not made ample enough, then the spots, too, can be made out on the board only with difficulty.

[Margin: 7.]

7. The best and most convenient method, however, is to observe the spots through the telescope, especially if it is used correctly. Thus the Sun, when it is rising or setting and is viewed through an optical tube, will betray whatever spots it has. Christoph Scheiner often contemplated them with a telescope in the Sun when it was girt by a thin little cloud. But I would not urge anyone to try anything similar. For it can easily happen that, as the clouds disperse, the Sun unexpectedly flashes its most brilliant light into the eye of the person using this eyepiece, and at a single stroke blinds him completely, through the violent concourse of the Sun's rays in the eye and the excessive heat arising from it.

[Margin: 8.]

[Margin: The most excellent way of observing the spots of the Sun.]

8. Therefore, among the other methods of observing the spots of the Sun already mentioned, the most excellent is the one carried out with the Helioscopic Machine, devised by C. Scheiner and almost always, and above all others, in use. This Machine is a special instrument, which he mentions in

Book 2, chapter 22, page 105; chapter 34, page 138; and at the beginning of the third book, page 151, where he describes it at length. For it is built of various parts, and also of small boards, by which the telescope is held fast and supported. Opposite the tube a little paper board is hung, standing at right angles, on which the Sun is received together with its spots. The whole machine, moreover, is very firmly joined together, so that one part cannot be moved without the other. But whenever the spots of the Sun are observed through this Machine, it must constantly be raised at one moment and lowered at the next, as the Sun either rises or descends. And because the Sun advances swiftly in its daily motion, anyone who wants to move the board and the whole Machine forward with this motion and to guide it must brace himself on bent knees, so that the Sun does not drop out of the observing circle. Truly, however, it is very difficult, indeed almost impossible, for one man to be equal at once to steering this machine more precisely with the motion of the Sun and to observing and marking the spots.

[Margin: 9.]

[Margin: Another method, the best of all, of observing the spots of the Sun, by means of an easily prepared Machine.]

9. After I had weighed the structure of this Machine more carefully in my own mind, however, I devised an easier and more convenient way of observing the spots, so that a single person can guide the Machine without difficulty and at the same time give himself to the observation. This method is carried out by means of a movable and revolving hole. Of this Scheiner, in his *Rosa Ursina*, Book 2, chapter 5 and page 73, affirms *that to accomplish it is a matter of no common skill, labour and expense*; and in chapter 6, page 74, he adds *that whoever has overcome this difficulty will achieve no common thing*. This invention, moreover, is suited not only to observing the spots but also to observing solar eclipses, in which it is required above all that everything be carried out as correctly and as accurately as possible. For this reason it will be worth the effort to describe the construction of this Machine here somewhat more fully and clearly, and at the same time to add the method of making observations with it. To this end, and so that an image of the Helioscopic Machine may be set and represented all the better before the eyes of the kind reader, I have chosen to append it, carefully engraved on copper, and to explain it.

Diagram. Full-page engraved plate, Fig. L: the Helioscopic Machine set up in a darkened room with a beamed ceiling, seen in perspective. In the left-hand wall a large ball turns in a round socket set in a hinged panel; a telescope passes through the ball, and a long rod runs from a bracket under the telescope down to the right, where it carries an upright board on which the Sun's image falls as a disc, the cone of light being drawn from the eyepiece to the board. The board stands on a platform that slides on two upright screw columns rising from a bench on trestles at the right, beside a window. On the back wall hang

two large quadrants and a cross-shaped staff; a toothed bar hangs below the right-hand quadrant. A small table at the left carries a horizontal sundial. On the floor lie the separate parts: a ball with a hole through it, a ring with its fittings, a dish, a tube with two clips, a second telescope, and a toothed rod with two hooks; dividers and a ruler lie on the bench.

- f (wall panel, upper left): label
- b (telescope tube at the ball): label
- c (eyepiece end of the telescope): label
- f (below the bracket under the tube): label
- e (the long rod): label
- a (the loose ball on the floor): label
- d (upper inner segment of the loose ring): label
- k (three times on the loose ring): label
- d (the dish in the ring): label
- b (twice on the loose tube, lower left): label
- r (twice, under the clips of that tube): label
- c (the loose telescope on the floor): label
- i (the toothed rod with hooks): label
- m (the ruler on the bench): label
- x (foot of the right-hand screw column): label
- y, m (bench top, at the left-hand screw column): labels
- n (upper platform of the right-hand screw column): label
- s (under that platform): label
- Letters on the bracket under the telescope, on the image board and inside the solar disc, on the left-hand screw column and its platform, on the toothed bar, and the letters and scale figures on both quadrant arcs: [?]

Blank verso of the plate (Fig. L); the plate shows through in mirror image.

[Margin: Enumeration of the parts of this Machine.]

[Margin: The first part is a double wooden window.]

1. This method of observing is indeed set up in a darkened room; yet the room certainly need not be as dark as the intense darkness required when the images of visible things set outside are carried onto a board and shown on it. For one window can even stay open, and the door too, without any hindrance. In a room of this kind one should have wooden windows in place of glass ones. From the middle of one of them a square piece of board is to be cut out, so that another small wooden window, fitted with suitable joints, can be put into the place of this opening, as appears from f in the accompanying figure L. In this small window a hole is again to be hollowed out, but a round one, to take a ball that moves and turns in every direction, towards every side; the ball is prepared in the following way.

[Margin: Sphere with tube.]

2. A sphere is to be formed, either of solid, dry wood, with a diameter equal to eight or nine digits, and turned exactly round; or it may be made

of brass, which is more durable (and which I too used). But this metal sphere should be hollow inside, so that its surface is only a quarter of an inch thick, lest it become unmanageable from too great a weight. This sphere should have a round hole bored through it, about two inches wide, so that a tube [canalis] b, likewise made of brass, can conveniently be inserted into it. The tube should reach a foot and a half in length and have two square clasps fixed on it, such as r shows, so that, like little sheaths, they can tightly take a square rod g eight or nine feet long.

[Margin: Ring and two plates of the Machine.]

3. This ball, formed in the way described, with the tube passing through its axis, is to be enclosed by a ring k (whose width should be one digit). For two plates d, curved and hollowed to the shape of the ball, surround it; they encircle the ball on every side and hold it in a firm joint, so that there is never any chance of its falling out. Yet by means of the tube b it can be moved and bent at will into every position, towards either side, upwards and downwards, without any difficulty, provided the ball is perfectly round. But so that no little crack may open anywhere through which light could get in, the ring k and the plates d are therefore to be lined with white soft leather.

Next, another small loop, namely e, is attached to the former ring, so that by its means the sphere can be fixed with nails to the small window f, as the accompanying figure makes plain.

[Margin: Use of these parts.]

4. This serves above all to let the machine always be taken out, together with the tube b and the small window f, when one does not wish to observe; and indeed, when the observation calls for another quarter of the sky — towards the east, the south or the west — to let it be inserted into another wooden window already intended and prepared for this use.

[Margin: Construction of an easier machine with a wooden sphere.]

A moving sphere of this kind can also be made at less expense out of another, cheaper material, namely solid wood, just as such a ball, fitted to a small window, is shown engraved on copper with all the necessary parts in the preceding Figure F. For here all that is required is a ball turned exactly round on the lathe, as it is there at k; and the small window l has a round hole bored through it, whose outer side should be smaller than the great circle of the ball. Next, let there also be ready a wooden ring whose hole is not wider than that of the small window already mentioned, as appears from m. The ball, then, the small window and the wooden ring are the three principal parts of this easily made machine. Accordingly, set the ball k on the turned hole in the small window l; over the same ball put the wooden ring m, draw it tighter with four wooden screws, and join it to the small window. When this is done, you will be able to bend and direct the ball, held between the small window and the wooden ring, to every side and every angle. But take care that no light can get in, and that you do not leave unstopped any little cracks there may be. By adjusting the screws you will

be able to make the ball's motion now looser, now tighter, according as you tighten or slacken them — which you could not do in handling a metal ball, because of its weight. Hence the wooden ball is easier to handle, for putting in and taking out, than the other one of brass. And although this wooden ball may seem an easy invention, if it is considered only in passing, yet it can also be usefully applied to many other things, such as the sextant, the radius and other astronomical instruments, which by its means can conveniently be moved in every direction. But it is not to the purpose to say more about these here.

[Margin: The bench and its parts.]

5. Next, for observing the spots a bench m is also required. It consists of several parts (its image is drawn in the accompanying diagram): first, of strong wood three feet long, resting on four supports so that it can stand without moving. Then two pieces of wood are to be fixed to this bench, set upright perpendicular to it and equal in length to four feet or thereabouts. These are cut with a thread of twisted spirals, are called screws, and are represented by x and y. Two nuts [Pericochlia] o o are passed onto these screws [trochleas], so that by their means the board n, which is to be set on the screws, can be raised or else lowered as occasion requires.

[Margin: Method of connecting this Machine so that it becomes one body.]

6. With these aids now prepared, one can then proceed to observing the spots. First, therefore, the small window, fitted together with the ball and the tube, is to be set into the larger wooden window. Next, a telescope of good quality is to be put into the tube, and the longer rod g into the clasps r. Opposite, moreover, the bench m is to be set up, with its upright screws and the board n. To the longer rod a small board h is to be fitted at right angles, which can easily be done provided the small board is thick enough. And on the back of the board two small clasps are added, into which a round iron rod i is inserted so that it can move; from it a plumb line is hung, so that by its means the vertical angle and that of the ecliptic, or rather the vertical point, can be observed.

[Margin: The way to handle this Machine and to observe the spots of the Sun.]

7. To this board a leaf of clean white paper is stuck with wax, and on it a circle is to be drawn, called the observing circle, as is seen in the accompanying figure. Afterwards the optical tube is to be directed at the Sun by means of the longer rod, which sets the ball and the small board in position together, so that the Sun falls with its rays on the board and lights up the observing circle. While this is being done, one must watch carefully whether the Sun's disc is larger or smaller than the observing circle s, z, u, vv, [?]. For if it is, then either the small board fitted on the rod must be moved further from the ball, or the telescope in the tube b must be drawn out or pushed in. This can be done without difficulty, because the optical tube set in the tube [canali] keeps its draw-tubes

[ductus] free and is packed only with a small linen cloth, to prevent either its falling out or the light of the Sun

penetrating at the sides through some chink. In this way the Sun's disc can be fitted quite exactly to the observing circle. Even so, it is always best at the outset to observe carefully and note how large a circumference the Sun's disc forms on the paper of the small board, according to the length of the rod and the distance, so that an observing circle of the exact size can be correctly determined and then used every time afterwards.

[Margin: What is required for making a proper observation of the solar spots.]

8. Before you begin the observation, however, have ready to hand a sundial [*ſciathericum Horologium*] divided at least into threes [*in terna & ternâ*] or, if possible, into single minutes. Next, on a small table placed against the other window, let a meridian line be accurately drawn, and set the sundial along it according to the horizon. After this the observation is to be made, in such a way that the Sun illuminates the observing circle. While this is being duly done, the spot is to be marked with a lead stylus. Meanwhile the plumb line is to be so directed that it falls on the centre of the observing circle, and by its line the vertical point is to be noted at s; at the same time the exact hour is to be taken from the sundial placed against the other window and entered on the paper together with the day of the observation.

[Margin: What is to be observed in the proper drawing of the spots?]

9. But do not be content with a single observation: soon make a fresh test of whether the new spot stands correctly, at a suitable distance both from the circumference and from the other spot, and likewise its size, appearance and shape. Further, whether it is denser or rather rarer, and whether it is furnished with a nucleus or not. With no less care you will note the faculae, if any are present — above all, in what place they first appeared or vanished, how they grew or diminished, whether they appeared brighter or rather dimmer, and the like — as frequent practice will teach anyone, and as is also evident from my own observations. It is especially worth noting that if separate spots or faculae are present, such that they cannot be recorded at one time, then a separate observation must be made of each, and likewise of its vertical point and exact time. For if you dwell on them too long, an error can easily be committed, because the vertical angle and that of the ecliptic change quickly, and with them the vertical point as well.

Diagram. A full-page engraved plate, worked on a dark ground, showing the apparatus for observing the solar spots set up in a darkened room. A telescope runs diagonally from upper right, where its end meets a faintly drawn round fitting in the wall, past a square lattice frame hanging from the ceiling, down towards the lower left; the Sun's light issues from its eyepiece end as a widening beam and falls on a white disc on an upright board mounted on a vertical

rod, the disc carrying a small dark spot. Along the left a long upright screw stands beside the board's support. At the right a bright window opening lets in daylight, and below it a small table carries a sundial with its gnomon. From the ceiling hang, besides the square frame, a pair of compasses or a triangular instrument and a cross-shaped piece. On the floor lie a bench on trestle legs, a large ring pierced with holes, a ball with a single round hole, and several rods and clamps.

- Lower left corner, inside the plate: an engraved inscription, not read [?].
- Small marks along the upper side of the tube near the square frame, and marks on the lit sheet at the window: not read; not settled whether they are letters.

Blank verso of the plate; the engraving shows through in mirror image.

10. Once, then, the Sun's spots, with their true colours, shadows and faculae, have been correctly recorded on one day, the work must be continued from day to day while the sky is clear, so that from these accurate observations of the spots their course and their remarkable change can be detected. [Margin: What must further be attended to in continuing the observations?] It is also worth noting here that the Sun always shows its face inverted on the board and the observing circle, so that the true eastern limb of the Sun is here z, and the western vv; likewise the upper part of the Sun in the ecliptic is presented in the observing circle as though it were the lower. Therefore, if the natural position of the spots on the Sun is to be represented, the observing circle, together with the spots and the paper, must be turned right over, so that the back of the paper becomes the front, and the part marked u takes the upper place, the part marked s the lower, z always the left, and vv the right.
11. [Margin: This method of observing the Sun's spots is preferred to Scheiner's.] Anyone who has tried both will admit that this method of observing is far easier and quicker than Scheiner's Helioscopic Machine [Machina Helioſcopica Scheineriana]. For here I can keep the Sun's disc, without any difficulty, both on the paper and in the observing circle, while I move the small board slowly and raise or lower it by turning the screws; or else, by laying one finger on the staff, I steer this whole machine — as experience, the mistress of things, will plainly teach anyone.
12. [Margin: The angle of the ecliptic and the vertical is required here, and how it is to be found.] Finding the ecliptic in the observing circle is very necessary, since without it every observation is imperfect. It is found through the angle of the vertical and the ecliptic, which is known in various ways, either mechanically or by means of calculation, as the teachers of spherical doctrine teach, and among others Scheiner too, in his *Rosa Ursina*, book 2, chapters 38, 39 and 40, pages 144 and 149. The method of finding this angle by calculation is indeed the most certain of all, but it is at the same time attended with great labour and trouble,

especially when there are many observations. I have therefore taken another course — not, indeed, the one Christoph Scheiner commonly used, finding the angle by a globe or an astrolabe, because here a slip of one or two degrees can easily occur;

but I constructed a special table, adapted to our pole height at Danzig [Gedanenſi Elevationi Poli], which is 54° 23′, in such a way that I computed all the angles of the vertical and the ecliptic for an entire year, for each degree of the ecliptic in the twelve signs and for every half-hour; and this one piece of work suffices for all time. However toilsome this labour may be, yet once someone has got through it, it is most welcome and pleasant, and the method of taking the angles from the table is very easy and less troublesome, provided account is taken of the proportional part. Nor is this method liable to error, either, if only we know the Sun's place to within a degree, and the true time of the observation: for these, known beforehand, at once show the angle. I have not thought it necessary to add the table itself here, since it serves only the latitude of the city of Danzig, where hardly very many devotees of Urania are to be found. Whoever wishes to set up observations of this kind in another place should, to reduce a great deal of labour and to gain time, undertake this task of compiling a table of the angles of the vertical and the ecliptic when he has leisure, and fit it to his own pole height; for by this very table the work of correctly recording the spots at the proper vertical point will be wonderfully lightened.

13. [Margin: The method of finding the ecliptic of the Sun's spots.] Once the angles for any observation of the spots have been found from the table just mentioned, you must first draw the perpendicular with a ruler from the marked vertical point through the centre of the Sun, from point s towards u. Then, if the time of observation is before noon, apply the angle to the observing circle by means of a semicircle correctly divided into degrees (which they call a transporter [Tranſportorium]), proceeding from the vertical line, or point s, towards the left, eastern limb z, and mark it on the circumference of the observing circle. Next draw a line through this point and the centre; you have then found the true ecliptic of the Sun and of the spots at the time of the observation. But if this observation was made in the afternoon hours, lay off this angle on the other side, the western, left [ſiniſtro] vv, counting from s. With the ecliptic now drawn in this way in all the figures and for each observation, it remains that the spots and faculae which were seen within 14 days or thereabouts, into one observing

circle should be brought, as far as possible, so that their daily and annual motion, and also their great alterations, can be detected more conveniently. This is easily done when you join the centres of the observed circles with a needle and lay one ecliptic on the other; for in this way the spots can be cleanly reproduced on another, clean sheet of paper. This must be done in all the remaining continued observations that you wish to publish. [Margin:

The method of drawing the observed spots.] Once, then, the spots have been brought onto one sheet and one figure, you should know that their position too is inverted, just as they were seen on the board during the observation. Therefore here too (as I also mentioned above, under number 10) all the spots drawn in one figure must be pierced with a needle, so that they become visible on the other side; for in this way, recorded afresh in their proper order on a clean sheet, they can be represented just as they actually performed their motion beneath the Sun, no differently than if you had seen them in the Sun with a telescope. This method of correctly drawing the course of the spots beneath the Sun is indeed attended with labour and tedium; yet the effort and eagerness to show their motion properly ought to bear and overcome every trouble. But this labour too could be reduced somewhat if an optical tube made of two convex lenses were used for it; for this tube shows the spots on the board in the same situation and position that they hold in the Sun, as I also mentioned above, in the second chapter. So let this be all I have to say on the method of observing the Sun's spots. If anyone perhaps finds some things here not explained clearly enough, I refer him once more to Scheiner's *Rosa Ursina*, for Scheiner wrote a lengthy treatise on this one subject. Meanwhile I have no doubt at all that, if the kind reader takes up the matter itself and arranges observations himself, he will readily and frankly admit that I too have set out sufficiently everything that bears on this.

14. [Margin: A most excellent method of observing eclipses of the Sun with this machine is likewise disclosed here.] This method of observing just described, by means of the spherical machine, can also be applied conveniently and usefully — indeed far more conveniently and usefully than all the others — to solar eclipses. If you do not wish to use the optical tube, in order to avoid the greater refraction, you may then take a glass convex glass of a flatter surface. Then draw the observing circle exactly on the board, and inside it describe five other, smaller circles, set at equal distances from the centre, to represent the ecliptic digits [digitos Eclipticos]. Indeed, so that you may observe every eclipse of the Sun the more accurately, you can form 24 concentric circles, so that they also show the quarters of the ecliptic digits. While the Sun is being eclipsed, then, you should carefully note, within the space of the two outermost circles, not only the true time of the observation and the vertical point, as you have been accustomed to do with the spots (from which the angle of the vertical and the ecliptic is afterwards found, and from that the ecliptic itself); but also, in all the phases and segments of the circle, mark very carefully the curved side of the eclipsed Sun, designated by three points in each segment of the circle, with respect both to the circumference and to the middle part — or, what is better, the whole line. From this you will then derive the exact diameter of the Moon, and also the place, with respect to the ecliptic, where the Sun first began to be eclipsed. You will see as well how the Moon passed beneath it and, as it were, twisted its course, and how the eclipse ended on the eastern limb; how great it was, and what angle the Moon's

orbit made with the ecliptic — provided the vertical points have been properly observed, by means of the plumb-line, at the defect of each digit. None of this, certainly, can be observed if the Sun merely passes through a bare hole into a dark chamber; for in that way the horns of the eclipsed Sun always fall blunted on the white board. Moreover, the eclipse of the Sun always appears smaller than it really is, as Kepler demonstrates in his *Paralipomena* to Witelo, chapter 1, page 54.

[Margin: Observation of an eclipse.] So that this method of observing solar eclipses may be understood the better, I shall give as an example an eclipse of the Sun that I observed in the year 1645, in the month of August, and I shall also add a diagram of the observation. In it the six thicker circles represent the twelve ecliptic digits; the finer, intervening concentric circles, the quarters of the digits; all the remaining sections of the circles are phases of the solar eclipse, of which there are 30; the numbers set beside them indicate how many digits those phases were. I had indeed intended to observe more phases, namely at the

Diagram. Engraved plate, *fig. M*: Hevelius's observation of the solar eclipse of 1645 August 21 at Danzig, drawn on the observing circle as described on the preceding page. A large set of concentric circles, alternately heavier and finer, fills the plate; it is crossed by many curved arcs, the successive phases of the eclipse, each marked at its ends or along its course with the number of digits eclipsed. The arcs carry no letters. The engraved caption, in a cursive hand inside the lower part of the circles, reads: "Observation of a solar eclipse made at Danzig in the year of the Christian era 1645, on 21 August." At the lower left stands "fig. M."; at the lower right, "Obſervatore et Celat. Io. Hevelio." ("Observed and engraved by Johannes Hevelius").

- Upper right, outside the rim: *Initium.* (Beginning), beside the label 7½.
- Left, outside the rim: *Finis.* (End).
- Left rim, set vertically at the level of the horizontal diameter: *Occidens.* (West).
- Right rim, set vertically: *Oriens.* (East).
- Digit labels on the left part of the rim, from the upper left downward: 6, 6½, 6⅞, a bare fraction ¾ (no integer engraved) beside it, 7, 7⅛, 7¼, 7⅜, 7½, ½ and ¾ (two bare fractions, no integer, set just inside the rim), 7¼ [?], 7¼, 7, 6½.
- Along the top of the rim, left to right: 5½ [?], 3, 5 (two separate labels, each over the end of its own arc), 4¼, 4, 4½, 5, 6, 6½, 7, 7¼, 7½, 7¾.
- Right rim, below the last: 7½, 7⅜.
- On a phase arc in the upper right interior, downward: ½ (a bare fraction, no integer), 1½, 2, 2½.
- On arcs in the upper central interior, left to right: 3¾ [?], 4½, 5, 5¼, 5¾, 6, 6½.
- Left of centre: a rotated sign [?] resembling a turned 3.
- Middle band, left to right: 4, 4¼, 7, 7¼, 7½.

- From the centre down and to the left to the lowest arcs: 5, 5½, 6, 6½, 6⅞, 7, 7⅛, 7¼, 7⅜, 7½, 7¾.

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contact of each segment of the circle. But small passing clouds and the unsteadiness of the air thwarted this plan of mine, so that I was unable to record more of them. The eclipse of the Sun began in the upper part, towards the right. Then the Moon passed further and further across the Sun and darkened it in the shape seen in the accompanying figure M, so that the greatest obscuration of the Sun here at Danzig [Gedani] amounted to 7¾ digits. After that it gradually decreased, so that the end was seen on the upper edge, towards the left.

As for the true time of each observed phase of this eclipse, I shall set that out here as well for students of astronomy. It was carefully determined not only by an accurate sundial [ſciathericū ſolare] set against the meridian line, but also by altitudes of the Sun, whenever these could be taken in spite of the clouds — as the following list shows, together with the digits and the phases.

Eclipse of the Sun observed at Danzig, in the year of the Christian era 1645, on August 21, New Style.

INCREASING OBSCURATION

Phases	By an accurate sundial set to the meridian line (time)	Altitude of the Sun by a brass quadrant of a cubit and a half	Times computed from it
Beginning	$11^h\ 23^m\ 45^s$		
½ digit	$11^h\ 27^m\ 0^s$		
	$11^h\ 31^m\ 30^s$	47° 15′ 0″	$11^h\ 31^m\ 6^s$
1½ digits	$11^h\ 33^m\ 30^s$		
2 digits	$11^h\ 38^m\ 0^s$		
2½ digits	$11^h\ 42^m\ 30^s$		
3½ digits	$11^h\ 45^m\ 30^s$		
4¼ digits	$11^h\ 56^m\ 0^s$		
5 digits	$12^h\ 1^m\ 30^s$		
5½ digits	$12^h\ 7^m\ 30^s$		
6 digits	$12^h\ 11^m\ 30^s$		
6½ digits	$12^h\ 16^m\ 30^s$		
6⅞ digits	$12^h\ 21^m\ 0^s$		

Phases	By the sundial (time)	Altitude of the Sun	Times computed from it
7 digits	$12^h\ 22^m\ 0^s$		
7⅛ digits	$12^h\ 25^m\ 0^s$		
7¼ digits	$12^h\ 27^m\ 0^s$		
7⅜ digits	$12^h\ 30^m\ 0^s$		
7¼ digits	$12^h\ 31^m\ 30^s$		
	$12^h\ 36^m\ 30^s$	47° 0′ 0″	$12^h\ 37^m\ 13^s$
7¾ digits	$12^h\ 41^m\ 20^s$	46° 50′ 0″	$12^h\ 41^m\ 52^s$
DECREASING OBSCURATION			
7½ digits	$12^h\ 45^m\ 30^s$		
7¼ digits	$12^h\ 50^m\ 40^s$		
7 digits	$12^h\ 54^m\ 45^s$		
6½ digits	$1^h\ 1^m\ 50^s$		
6 digits	$1^h\ 6^m\ 0^s$	45° 40′ 0″	$1^h\ 6^m\ 8^s$
5¾ digits	$1^h\ 8^m\ 30^s$		
5¼ digits	$1^h\ 12^m\ 20^s$		
5 digits	$1^h\ 15^m\ 30^s$	45° 5′ 0″	$1^h\ 15^m\ 36^s$
4¼ digits	$1^h\ 20^m\ 0^s$		
4 digits	$1^h\ 23^m\ 45^s$	44° 20′ 0″	$1^h\ 24^m\ 25^s$
3 digits	$1^h\ 31^m\ 30^s$		
¾ digit	$1^h\ 47^m\ 30^s$		
about ½	$1^h\ 49^m\ 0^s$		
End	$1^h\ 53^m\ 0^s$		
	$1^h\ 56^m\ 0^s$	41° 55′ 0″	$1^h\ 55^m\ 50^s$
	$2^h\ 26^m\ 0^s$	38° 44′ 0″	$2^h\ 26^m\ 40^s$
	$2^h\ 30^m\ 0^s$	38° 24′ 0″	$2^h\ 30^m\ 0^s$

CAPUT VI.

Chapter VI.

On the Moon in general, its spots, its light, the manner of its illumination, and other matters bearing on this that are most worth knowing; and both what the company of the ancient philosophers thought about all these things, and what the more recent astronomers and philo-mathematicians establish from sure and infallible arguments grounded in nature: a short dissertation.

[Margin: The heavenly bodies have been arranged harmonically by the Creator.]

Just as God, thrice Best and Greatest, in his immense wisdom and inscrutable counsel created the heavenly bodies to a definite measure and size, so no less did he set them apart, placing them in a definite order and at definite distances; indeed (as very many men of the highest intellect and wisdom have become fully convinced) he brought them into a true celestial harmony. Among all the heavenly bodies, moreover, he assigned to the Moon the lower place in the heaven (to speak in the common way) and the one nearer the Earth — a point that no philosopher or mathematician of our age doubts at all.

[Margin: Why God assigned the Moon a place nearer the Earth.]

And beyond doubt he did this not only for this purpose — so far as our feeble human intellect perhaps allows us to infer — that the Moon might extend its operation upon the Earth the more effectively and shed stronger rays upon us dwellers on Earth; but rather so that, from its notable size, which arises from its nearer distance, its strange face, the wonderful changes of its phases, and its very swift and varied motion might be recognised, explored and weighed more easily and more surely than those of the other stars. The purpose, namely, was that by its help the remaining ethereal bodies, more remote and smaller in appearance, might be surveyed and weighed by reason and mind with better success — if not completely, then at least somewhat more truly; and indeed that the Creator of Heaven and Earth himself might be looked up to, honoured and celebrated on account of these wonderful works.

This final cause, indeed, those ancient pagan philo-

sophers, as they did not consider it from every side, were also unable to attend to, since they were deprived of divine light. Nevertheless, it is more than sufficiently evident from their writings that the Moon was held by all to be the first teacher of the heavenly discipline — because, namely, both its course and its variety readily strike the eyes, and it leads the mind without difficulty, as if by the hand, to a better knowledge of the other, more remote heavenly bodies: for of bodies less remote from us we have a greater knowledge, and one that falls more upon the senses.

[Margin: The Moon was held by the ancients to be the first teacher of the heavenly discipline.]

For this reason, right at the outset, they set the astronomical ladder against the Moon, hoping (and not in vain) that by its help one could gradually, and in time, go further and reach the remaining stars, and explore with the eyes and with the mind both their motion and their nature and essence.

[Margin: The ancient philosophers held various opinions about the Moon.]

They therefore cherished various and remarkable opinions about the Moon's shape, its spots, its light and its nature; and never on any subject did weightier and more vehement clashes and disputes flourish among those ancient philosophers than on this one. In what follows I am quite of the view that, not only briefly but above all, the erroneous opinions among these must be refuted, and conversely the true ones established more and more firmly — freely admitting, indeed, that the task I must take up in this way is an exceedingly arduous one, both in examining the doctrines of the ancients and in laying open the natural face of the Moon, so that we may not admire a work invented in the brains of men rather than one made by the fingers of God the Creator.

[Margin: Clearchus and Argesinax thought that the face of the Moon is an image of the Ocean.]

First, then, some of the most ancient philosophers — Clearchus and Argesinax above all — thought that the lunar spots were mirror-likenesses and images of the great sea appearing in the Moon, passing across to us by reflection, as Plutarch attests in his book *De facie Lunae* [On the Face of the Moon].

[Margin: This opinion is refuted.]

Both the falsity of this view and the impossibility of the thing itself, however, are very plainly evident from this. It is certain and beyond all doubt that the Moon moves round the whole Earth, and that it does so not only by its own motion, in about 27 days, but also by the diurnal motion — namely, as the Peripatetics hold, in the space of 24 hours — so that it becomes visible to all the inhabitants of the earth in every place whatever. It would therefore be altogether necessary that the Moon, as regards both its aspect and the spots' position and

shape, should vary at every single moment — which, however, is far otherwise.

[Margin: Since the lunar spots are not variable, they cannot be mirror-images.]

I say nothing of the fact that rays falling obliquely on a mirror can reach only the part turned directly opposite; for which reason all the images of those things that are on earth would be reflected not to us but into the sky. Moreover, when the Moon is setting for us and rising for the Antipodes, quite different spots would appear to them than to Europeans: for since the sea, together with the continent, presents a different shape there, other spots, different and changed, would certainly appear by reason of the reflection — which plainly conflicts with experience. For we never read that those larger spots, known to the ancients, have varied at any time, so far as has been handed down to memory; and the present-day observations of those who sail across the Ethiopian, Pacific and Indian seas confirm this more than sufficiently.

[Margin: Empedocles held the Moon to be a mixture of murky air and coal-like fire.]

2. Others, such as Empedocles and very many of the Stoics, held — as Plutarch attests — that the Moon is a mixture and blending of murky air and coal-like fire; that it is not something kindled of itself and having its own light, but a kind of dark body, always smoking and burnt by fire; and hence that it is partly luminous by reason of the fire, but partly dark by reason of the murky air.

[Margin: Diogenes maintains that it is of pumice.]

Diogenes the natural philosopher judged it to be of pumice — indeed glassy, translucent, and in part also dark. Pythagoras, Anaximenes, Parmenides and Cleantes [Cleanthes] called it a fiery body. For Zeno, the pupil of Parmenides, it was a fiery star, endowed with mind, both wise and fashioned with craft — as Francesco Patrizi attests in the *Pancosmia*, book 20. But these opinions need no refutation, since there is no one in this age of ours who embraces them.

[Margin: Very many others held the Moon to be a fiery body endowed with mind.]

[Margin: Others thought that the lunar spots arise from certain bodies lying between the Moon and the Sun.]

3. Others were of the opinion that certain bodies lying between the Sun and the Moon block the way of the Sun's rays to certain parts of the Moon, the spots taking their origin from this. What sort of bodies these are, however, I do not understand. For if they were clouds, the spots would be continually changing; yet they remain unchanging. And if they were sunspots, to whom, I ask, were these known at that time? And granting that something of the kind could arise from those spots, it would still not be enough to have attended to this here, since they too change, both in position and in sub-

stance; indeed, they sometimes vanish entirely from the Sun sooner than expected. Such a change would then befall the lunar spots as well — which plainly runs wholly counter to experience.

[Margin: Diogenes held that the Moon is movable and turnable about its axes, having its own light on one side and on the other sharing in no light at all.]

4. Diogenes Laërtius [Diogenes Laertius] reports that Berosus the Chaldean taught that the Moon has its own light on one side, but on the other is entirely dark; so that, from the turning of its body, the light grows daily until the whole luminous hemisphere is visible. The impossibility of this, too, is easily gathered from the following. If some particular spot were situated, for example, at the western limb in the phase of the sickle-shaped waxing Moon, that spot would necessarily move little by little towards the east, and would always follow the section of light and shadow right up to the full Moon; at which time the already mentioned spot would have to be seen no longer in the west but in the east. This, however, is not observed.

[Margin: The lunar spots always keep a fixed place.]

On the contrary, if some spot clings to the more westerly periphery around the new Moon, in some phase soon after conjunction, it stays there, although the Moon's light grows daily — so much so that the spots almost always keep a fixed place, and only one hemisphere is visible to us.

[Margin: Some libration of the disc is observed in the Moon.]

Nonetheless, the Moon librates a little; of this we shall treat more fully in its proper place and time.

[Margin: The Peripatetics hold that the Moon consists of denser and rarer parts.]

5. The Peripatetics leave no stone unturned to establish denser and rarer parts. The denser parts, they say, represent the brighter part of the Moon, on account of their greater resistance; the rarer, on account of their lesser opacity, represent the spots. But they do not all agree among themselves. For some hold that the brighter spots of the Moon arise from the rarer parts, because these absorb more light; but that the darker spots are produced from the denser parts, because they do not retain as much light. This is because they imagine that the Moon is seen not by the Sun's

reflected rays, but because, illuminated and filled by the Sun, it pours out the Sun's light.

[Margin: d'Aguilon calls the denser parts more opaque, and the rarer parts purer from the taint of opacity.]

François d'Aguilon, however, in book 5 of his *Optics*, p. 422, calls the denser parts "more opaque" and the rarer parts "purer from the taint of opacity". However that may be, it comes to the same thing, and this view is not confirmed any the better for it. For if the lunar spots (I am not speaking here, however, of those larger ones which with the naked

eye are seen, but of the remaining smaller ones, which the more recent writers hold to be mountains and valleys, and which become visible only to the armed eye) kept some constant and invariable colour at all times, this opinion would carry some appearance of truth.

[Margin: Certain lunar spots are subject to continual variation of light and shadow.]

But the smaller lunar spots just indicated vary their light and shadow from day to day, indeed from hour to hour. For not only do they become darker or brighter, larger or smaller, and finally quite brilliantly bright; the darker part — namely the shadow — is also carried continually round in a circle, follows the motion of the Sun, and falls on the side opposite to it, in accordance with the nature of a shadow arising from the Sun. And that the casting of a shadow cannot happen otherwise is proved altogether clearly from optics, and indeed by d'Aguilon himself, who says in book 5 of his *Optics*, prop. 60, p. 424: "An opaque body casts a shadow toward the side opposite the light." For an opaque body is impervious to light, as the author just named puts it in book 5, definition 3, p. 358; or, as Franciscus Patritius [Francesco Patrizi] says in book 2 *On the Diaphanous*: "Opaque is that through which there is no passage for light."

[Margin: An opaque body resists light.]

It is therefore most certain that where there is shadow, there an opaque body is also present, as the efficient cause of the shadow; for a diaphanous body cannot spread a shadow from itself, since it is pervious to light.

[Margin: An opaque body casts a shadow.]

With these things presupposed, it necessarily follows that if some opaque body casts a shadow from itself, it is also higher than the other parts; and these higher and lower parts can surely be compared to nothing more fittingly than to mountains and valleys.

[Margin: From higher mountains a longer and darker shadow arises.]

The higher these mountains rise, the longer and darker the shadow they cast; the more gently they slope, the smaller and weaker. This again is proved from d'Aguilon, book 5, from the corollary to prop. 61: "A larger opaque body produces a larger shadow"; and in the same place: "The more rays of the luminous body an opaque body intercepts, the larger the shadow it produces." Much more could indeed be said on this subject at present. But since this opinion, that there really are mountains on the Moon, will be confirmed

further on, let us defer what remains to a more suitable occasion. For in the explanations of the lunar figures [Iconismi] this can be done with less labour, as by a demonstration to the eye, so that hereafter we shall discuss this matter as far as suffices.

But if these philosophers just mentioned want their rarer, denser and more opaque parts to be understood as though they were certain things that could not unfittingly be compared with certain terrestrial things — marshes, forests, waters and the like — then certainly these points would not only be readily granted; it could also be shown amply enough that they are not absurd. But I very much doubt whether in this respect (difficult as they usually are) they will yield, not only to us but also to the truth; and perhaps they will even greet these words with an outcry, because they run counter to their master.

[Margin: The Aristotelians say that the Moon consists of a brighter, immutable and incorruptible matter, and that it is a fifth essence.]

For with this Aristotle, and likewise with Pliny the Elder, Ptolemy, Tycho, Scaliger, Fromondus [Libert Froidmont] and others, they prefer to lay down — indeed to establish with all their might — that the Moon, since it is of the number of the stars, consists of a brighter, pellucid, incorruptible and immutable matter, and is subtler than fire itself and water; moreover, that it is a perfect substantial light; that this matter stands only analogically to elemental matter; indeed, that it is a fifth essence, which has a homogeneous matter.

To this I reply, first, that the Moon is entirely dark and endowed with no light of its own, but borrows all its light from the Sun; and that it therefore cannot in the least be a diaphanous and pellucid body.

[Margin: The reason why the Moon is entirely dark and endowed with absolutely no light of its own.]

This opinion certainly needs no demonstrations, since even to the less learned it is well enough established from the decrease and increase of its light, as also from the alternation of its phases, by which it appears now full, now gibbous, halved and sickle-shaped. For if it had light of its own, or were a diaphanous body, it would always be seen full of light, even at the time of an eclipse, when it runs into the Earth's shadow. And at the very time of an eclipse of the Sun (which arises solely from the interposition of the Moon between the Sun and our eye) there would be no darkening at all, if it were a diaphanous and pellucid body: for in place of the solar light which it then seems to cover, it would pass on to us either its own proper light or, by reason of its diaphanous substance, the Sun's.

[Margin: Do lights and colours penetrate diaphanous bodies distinctly?]

For in optics we are taught that light which is not impeded is necessarily carried through the whole sphere of its activity in an instant, and that lights and colours penetrate diaphanous bodies distinctly. But solar eclipses confirm the contrary: they have very often brought such darkness that not only did stars shine out around midday, but also

birds fell from the air to the earth, as various trustworthy historians testify: (1) Herodotus, book 2, on the war between the Lydians and the Medes; (2) Thucydides, book 2, in the first year of the Peloponnesian War; (3) Ptolemy, book 5 of the *Great Work* [the *Almagest*], chapter 11, and Theon [Theon of Alexandria] in his *Commentary*; (4) Julius Capitolinus, in the year of Christ 237, April 12; (5) Ammianus Marcellinus, book 20; (6) in the year 1187, September 4; (7) in the year 1560, on August 21, with Clavius [Christoph Clavius] as witness: "At Coimbra the Sun lay hidden around midday, covered for no short time, and the darkness was in a way greater than that of night; for one could not see where to set one's foot, and the stars appeared very clearly in the sky; birds too, marvellous to say, fell from the air to the earth in terror at so foul a darkening."

[Margin: That the densest darkness has very often occurred in solar eclipses is proved by various examples.]

Moreover, whenever the Moon passes between some star and our eye, the star is wholly covered and darkened by it, so that it appears nowhere — which would otherwise be impossible if the Moon were only partly diaphanous. Therefore the Moon is rightly called an opaque body, indeed a most opaque one, and altogether impervious to light: with optics, that is, as judge, as has already been shown sufficiently, which defines an opaque body as one that resists the rays of a luminous body and does not permit their passage.

[Margin: The Moon is rightly held to be a most opaque body.]

[Margin: Some say that the Moon is partly opaque and partly lets light pass; others think otherwise.]

But there are indeed those who distinguish opacity from transparency [perspicuitas], saying that the Moon is not wholly opaque, nor wholly impervious to light. Their opinion divides into two parts. For some hold that it is penetrated by light to some part of its depth, but not through the whole. Others hold that it has some parts that are transparent through its whole depth; that the Moon is not only illuminated by the Sun on its surface, but drinks in the Sun's light to some part of itself; and that the Moon does not pour the solar light back to us here by reflection — in which manner it would pour it back from its outermost surface alone, as mirrors do — but pours it back as something infused. So Claramontius [Scipione Chiaramonti] records in book 7, chap. 10, p. 157.

[Margin: Claramontius thinks that the Moon passes the solar light on to us not by reflection, but as something infused.]

And he continues thus in the same place: "The light of the Sun is incorporated in the Moon, so that the Moon is a transparent and translucent body, at least around its surface, and perhaps throughout, although because of the size of the lunar body the light of the Sun cannot penetrate the whole lunar body; so that the light appears equally in the part of the Moon turned away from the Sun as in the part of the Moon turned toward the Sun. Thus the light of the Moon which we see is not only the light of the Sun reflected upon the body of the

Moon, but the light of the Sun imbibed and incorporated by the Moon." How much weight these things deserve, from the

earlier eclipses and occultations of stars is more than sufficiently clear.

[Margin: In lunar eclipses a varying colour is observed.]

Others, however, hold that the whole Moon is penetrated by the light of the Sun only through certain parts and small fissures [rimulae]. They try to demonstrate this from the different colours of eclipses of the Moon: for since at that time the Moon can in no way be illuminated by the Sun's rays, because of the Earth lying between, there must necessarily be at least some part of light of its own. I, for my part, do not deny these colours; rather, I confirm them. For when an eclipse of the Moon occurs at apogee, the Moon passes through a sharper shadow (which becomes the sharper, the farther it lies from the body of the Sun, which is larger than the Earth); for this reason the Moon is seen redder and a little brighter than at perigee. At perigee it moves through a denser, darker and blacker shadow, and therefore it also appears gloomier, darker and blackish, as experience testifies.

[Margin: The colours of eclipses do not arise from the Moon's own light.]

[Margin: Light shines out more brightly in a darker medium.]

That these colours do not arise from the Moon's own light, implanted by the power of creation, optics clearly proves; and this is its most trustworthy axiom [pronunciatum]: the darker the medium, and the freer from the first and immediate light, the more brightly light shines out when it is reflected together with the forms of things. For every luminous body appears the brighter, the darker its surroundings are. Likewise, who does not know that the Moon can be seen better by night than by day? It would therefore follow that the colours of lunar eclipses are darker near apogee, but brighter near perigee. From these things it is plainly established that that feebler light, or the colours that appear in eclipses, arise not from the Moon's own, implanted light, but from the light of the Sun, together with the secondary light of the Moon that is observed around the new moons. More will be said about this below, especially in chapters 12 and 13.

[Margin: It is proved by examples that the eclipsed Moon has sometimes vanished from the sky altogether.]

And yet it has also become known from various examples that very often, at the time of total obscuration, the Moon has been stripped of all colours and wholly darkened, so that it withdrew itself from sight altogether. This could never have happened if it had even a small particle of light of its own, as the followers of the Peripatetic philosophy would have it. Thales of Miletus and Anaxagoras, the most ancient of philosophers, already recognised this in their own times, as Vitruvius reports (book 9, chap. 4); as also, in our own age (to say nothing of others), Kepler

[Margin: First example.]

, the mathematician of three emperors, did, as may be seen in his *Astronomiae Pars Optica* [Aſtronomiâ Part. Opt.], p. 297, where he writes: *"In the year 1601,*

in December, when only a very thin horn remained, I did not see the dusky part." And again in the *Epitome Astronomiae Copernicanae* [Epitome Aſtron. Copernic.], book 5, p. 825: *"The Moon is sometimes suddenly lost altogether, so that not even a trace of it appears, although fixed stars of the fourth or fifth magnitude can be seen very close to its place; so in that case the suspicion of an excessively murky air has no place. So it happened in the year 1620, on June 5/15."*

[Margin: Second example.]

[Margin: A similar example, observed by the author.]

It also fell to me to notice a remarkable example of this kind in the year 1642, on April 15/25. For at the time of total obscuration the Moon vanished entirely, so that not a few of the spectators could neither find the Moon's place in the sky nor point it out; and although we were equipped with a telescope, the Moon nevertheless eluded our sight, even though stars of the fourth and fifth rank were plainly visible.

[Margin: Johannes Phocylides also observed this same eclipse at Franeker.]

That this is so is likewise attested by Iohannes Phocylides [Johannes Phocylides Holwarda] in his *Epitome Astronomiae reformatae*, p. 65, where he says: *"When the eclipse was already about at its greatest, and the clouds had been driven off a little by a rather strong wind, the sky all round, for nearly a quadrant about the place of the eclipsed Moon, was restored to view so clear that even stars of the fourth and fifth magnitude could be accurately distinguished and counted all round the Moon. Where, meanwhile, was the Moon? It had vanished so completely that, whether with the naked eye or with the aid of the viewing tube, not even the least trace of it was noticed in the sky, as if it had been drawn down by some magic spell."* So he writes. The observers at Utrecht [Vltrajectenſes] also observed the same phenomenon at the same time.

[Margin: The Peripatetics do not give credit even to astronomical observations, if these seem to fight against their preconceived opinion.]

Although what has been adduced demonstrates quite clearly that not even the smallest particle of light inheres in the Moon, I nevertheless doubt that the Peripatetic philosophers will give credit to these observations. Even if they were to see it with their own eyes, they would rather ascribe it to a deception of sight, as they usually do. What, then, shall I answer to this? Nothing else at all than what the most learned Johannes Fabricius said, groaning, in his narration on the sunspots:

[Margin: We are so obstinate that the senses scarcely find credit any longer.]

"Alas! Our obstinacy has gone so far that even the senses no longer find credit; indeed, imagination has such a prerogative in judging the truth that we scarcely allow our obstinacies to be refuted by arguments drawn from the senses. For this is innate in most of us: even if they have lost their case once the error has been demonstrated, they not only do not yield, but fight on even from their knees against the manifest truth." So he writes, and most truly. Meanwhile, although they do not believe these things at all, nevertheless

[Margin: We beg the Peripatetics again and again not to begrudge us our eyes.]

we would not wish to be angry with them on that account; rather, we shall most willingly leave them their pertinacious and obstinate mind, earnestly asking only that they not begrudge us our senses and eyes. For these confirm these things and others, incredible to them but well founded in nature, and also rouse, move and drive our minds to believe such things.

[Margin: The variety of colours seen in the celestial bodies proves that the Moon too consists of heterogeneous parts.]

But lest I seem to digress too far, I shall turn back to the Moon. The diverse colours of the stars testify that it is neither a fifth essence nor composed of homogeneous parts. For one colour appears in the Heart of the Lion [Corde Leonis], another in Palilicium [Palilicio], another in Spica, another in Sirius, another in Canis Minor or Lyra, and another in Arcturus.

[Margin: The colours of the stars do not arise from the Earth's vaporous sphere.]

These colours, however, in no way take their origin from our vaporous sphere (otherwise all stars at an equal altitude would also be seen tinged with similar colours), but inhere entirely in the celestial bodies.

[Margin: Colour is a sure proof of opacity.]

Since, therefore, the light of the stars is coloured, as experience witnesses, it is necessarily granted that a certain opacity is also present in those bodies, and it is rightly affirmed that the stars are not pellucid and transparent; for colour is almost nothing other than light mixed with shadow arising from some opacity.

[Margin: The diaphanous is devoid of all colours.]

But the diaphanous, as the genuine medium of light, must be devoid of all colours; otherwise the transparent light would be mixed, which rightly does not occur in a fifth essence.

[Margin: By what reasons do the Aristotelians strive to prove the incorruptibility of the Moon?]

Further, the faithful followers of Aristotle try to prove by the following reasons that the Moon is an incorruptible body, subject to no changes. First, that from the beginning of the world to this very day it has been carried with a steady and constant motion. Second, that not even the least change, let alone generation or corruption, has ever been noticed about the Moon. But in truth, who is so ignorant as not to know that our Earth too, corruptible as it is, has likewise existed through so many years on this world's stage, and will endure to the very last day together with the Sun, the Moon and the other ethereal bodies?

[Margin: Why are generations and corruptions not detected on the Moon?]

Moreover, that no generations and corruptions have ever been detected on the Moon, while on the Earth very great alterations are noticed in cities, regions, trees, plants and animals, is no cause for wonder. For if it were granted

us to inhabit the Moon for some definite time, and if from there we were permitted the Earth with our eyes, with the best tele-

scopes, to contemplate it: we would certainly never detect changes greater than the lunar ones (which, however, concern only the outer parts), nor buildings, nor towers, plants, trees or animals clinging to the surface of the Earth. But more marvellous things would appear to us living on the Moon, especially if some prior notion went before: that on the Earth, that dregs of the world, so many animals of every kind, flying, creeping and four-footed alike, and above all so many myriads of men, can live and multiply themselves through the generations.

[Margin: Although the Moon may support neither men nor brute animals, it is nevertheless possible that something else is found there.]

It does not follow, therefore, that because we see nothing, nothing exists there either. Perhaps in so vast a body, excellent beyond what can be said, certain more distinguished things are found; even though there are not, in that place, men, brute animals, trees, plants, crops or anything of that kind wholly similar to our earthly things, nor lightning, winds or rains.

[Margin: On the Moon there can be things wholly different from ours and surpassing our thought.]

Meanwhile, however, I do not see why there should not be there certain other things, most different from our earthly ones and most remote from our imagination, in short wholly beyond our power to conceive, which can nevertheless be generated, changed and dissolved. Galileo, a man of consummate subtlety, discusses many points on this subject in his *Systema Mundi* that truly deserve to be noted, saying:

[Margin: If someone were deprived of knowledge of the element of water, he could imagine nothing of ships and fishes.]

"Just as I have no doubt that if someone had been born and brought up in a vast forest among wild beasts and birds, and had never known anything of the element of water, such a man would never by imagining conceive that there is in nature a world different from the land, full of animals that move swiftly without legs and without wings — and not on the surface only, as beasts do on the land, but deep in its very depths; and that not only move, but stay motionless in whatever place they please, which birds in the air cannot do; and that, moreover, men also live there, build palaces and cities there, and enjoy so great a shortening of their journeys that without any labour they carry themselves, with their whole family and house and with entire cities, to the most remote regions — just as, I say, I know for certain that such a man, even if endowed with the most penetrating imagination, would never have thought of fishes, of the ocean, of ships and fleets: so equally, indeed much more, it can happen that on the Moon, removed from us by so great an interval, and having matter perhaps most different from the Earth's, certain substances exist and produce operations not merely remote from our imagination but wholly foreign to it, since they bear no likeness to ours and are therefore altogether at

variance with our thought. For whatever falls under our imagination we must either have seen before, or it must be composed of things, or parts of things, already seen, such as sphinxes, sirens, chimaeras, centaurs, etc."

[Margin: Human conception and imagination are not only weak but also deceptive.]

Moreover, that this is so — that our human intellect, conception and imagination are not only weak but also deceptive — is gathered from things found here on the Earth itself, namely in foreign regions. For who would ever have imagined, had he not first been taught it, that in Africa and America there were so many marvellous kinds of animals, so many kinds of crops and plants that the mind had not foreseen, so many innumerable foreign kinds of snails and shells?

[Margin: What the common people do not perceive, they count among absurdities.]

But for the most part this is how it is with us, and especially with the common people: whatever they have neither seen nor perceived, or cannot behold with their eyes, recognise, or grasp with their dull minds, they at once count among the absurd and the impossible, and no less regard everyone who contradicts them as stupid, foolish and out of their minds.

[Margin: Those who allow something to be proved to themselves by reasoning alone, and not at the same time by the experience of the senses, run the greatest risk.]

Further, to show the Peripatetic family, if only in passing, how cautious and circumspect we ought to be in assenting to things urged on us by reasoning alone, even when they make a great show, unless they are confirmed and demonstrated by the experience of the senses — and how great a difference there is between rational conjectures and ocular experience — I therefore ask them to answer the following questions. Could Aristotle, with all his followers, ever have imagined that the Milky Way is a heap of many very small stars, before this was detected with the optical tube?

[Margin: Without the tube it was impossible for Aristotle to understand the Milky Way correctly.]

Or that Venus and Mercury wax and wane like the Moon? Still less that such very large opaque bodies exist — I mean the solar spots, to say nothing of the rest — and are generated and corrupted in the very heaven, not far from the Sun? And yet (as I readily understand) those same men will by no means embrace this last assertion; and this, indeed, on the ground that they have almost never seen such phenomena with their own eyes, nor wish to see them, lest by that very ocular demonstration they be forced to change their false preconceived opinion and to settle on the contrary.

[Margin: In the other bodies too there can be things entirely remote from our imagination.]

From all of which it plainly becomes manifest that very many other things can be found, on the Moon as well as in the other celestial bodies, which we

men have not been able, to this very day, to reach either by the sense of our eyes or by our reason. Yet I rely on a sure hope

[Margin: The time will come when the day, and the diligence of a longer age, will draw into the light the things that now lie hidden.]

that in time, and before the end of the world, a great many things will be uncovered and revealed to us, of which posterity will have such knowledge as we can now scarcely imagine — just as in this age, too, many things have become known to us that were wholly unknown to our ancestors of old. For such an order, succession and growth has always pleased the supreme Architect of the World, in ecclesiastical affairs as much as in political ones, in the arts and in the sciences. But since it is not the business of this place to demonstrate these things at greater length, let us therefore turn to examining the remaining opinions about the Moon.

[Margin: d'Aguilon and Scheiner hold that the hidden hemisphere is perfectly diaphanous, and the open one only half-diaphanous.]

6. There are, besides, those who hold (above all the most learned François d'Aguilon, as also the distinguished Christoph Scheiner, in the *Disquisitio Mathematica*, p. 62) that one hemisphere of the Moon is perfectly diaphanous, while the other — the one, that is, which shows us the appearance of a human face — is only half-diaphanous [medio-diaphanum]: sprinkled, that is, with a certain opacity which lets some light through, but retains the greater part, not only at the outermost surface but also in the depth. They consider that the same thing happens in that milky circle of the heaven as well. Next, they teach that the more opaque part of the Moon is not unlike a denser cloud, which likewise blocks the sight of the Sun.

But here the blocking of the solar rays must be distinguished. Such a cloud does indeed block the primary light of the Sun, so that a shadow follows; but not the secondary light of the Sun, from which darkness arises — as can be seen in total eclipses of the Sun, when such a gloom comes about that not even the secondary light can penetrate. And that a wall or a house, though they are most opaque bodies, produces only shadows and not darkness, even though they give neither the primary nor the secondary light entry or passage through themselves — the reason is that reflection takes place from the surrounding light into that shadow.

[Margin: The part of the Moon turned away consists of the same parts, and has no share in any light of its own, as the part of the Moon turned toward us.]

Moreover, the foundations of the opinion set out can also easily be destroyed, if it is demonstrated that the part of the Moon turned away from us, or the invisible hemisphere, is of the same nature and consists of the same parts as the visible hemisphere turned toward us, and indeed possesses no light of its own whatever. And this, indeed, with no trouble

can be done, namely from that new motion of libration which has been discovered. It will become clear, above all from the lunar figures [Iconismi]

that are to be added, that the Moon does not always present the same face to our eyes, but at a certain time turns toward us, and offers to view, no small part of its hemisphere that is hidden from us. Since this is really so, and can be amply established from the limbs of two full moons, taken at the limits of greatest and least libration, the claim that the hidden hemisphere is perfectly diaphanous will therefore collapse entirely. For if it were otherwise, truly wonderful and strange phases would arise from it. As for the claim that the Moon is sprinkled with a certain opacity, that is sufficiently refuted by the reasons already given.

[Margin: The Moon sometimes turns toward us a fairly large part of the hemisphere hidden from us.]

[Margin: If the hidden hemisphere were diaphanous, strange phases would arise from it.]

7. There remains the opinion of Scipio Claramontius, the sworn enemy of all the mathematicians who oppose the Peripatetic philosophy on certain points. He sets it out in his *De Universo*, book 8, chapter 9, p. 183, in these words: *"I propose for consideration that the colours in the heavenly bodies — since they do not proceed from any temperament, but reside in a body of the simplest nature — emanate from the form alone: thus the redness in Mars, the leaden hue in Saturn, the yellowness in Mercury, etc.; and in the same way the darker and lighter colours in the Moon. That is, the Moon is, as it were, painted, and no other cause of its colours can be adduced than the cause of the redness in Mars, of the leaden hue in Saturn, etc. But why it pleased supreme nature to make such a painting in the Moon is not within our faculty to know; it is rashness to claim the knowledge of it."*

[Margin: The singular opinion of Scipio Claramontius on the lunar spots.]

I am certainly surprised. This man (who fancies himself I know not whom) is never at any time at a loss for anything at all when it comes to attacking and refuting the arguments of all the mathematicians — indeed even the ocular demonstrations brought forward against Aristotle. Yet on this point, namely the lunar spots, he at once took refuge in the omnipotent and divine will of GOD, asserting that it pleased the Creator of Heaven and Earth to create the Moon painted in this way. I grant indeed, with both hands, that many very abstruse questions can be resolved without any trouble in this way, if we say that it comes from the will of GOD that things are made as they are. Nevertheless, I hold that this should be permitted only to common people, as being little versed in logic, metaphysics and physics. But if the most learned men walk this path of philosophizing — men who think that not only in physics but also in optics and astronomy they are much wiser, or of keener judgement, than all the Gali-

[Margin: It is not fitting for those who treat philosophical matters to take refuge at once in the omnipotence and divine will, as in some sacred anchor.][6]

[6]in the side-note on the sacred anchor, the Toronto copy reads «anchoram,», with h.

leos, the Tychos, the Gassendis, the Keplers (as Claramontius wishes to be seen as such a man, when in his treatise *De Universo*, book 7, chapter 10, p. 159, he passes judgement on Kepler's judgement) — that can hardly be tolerated in any way. To do this would indeed not be wrong if the mind supplied us with no reasons at all, and no ocular experience or demonstration were at hand, so that it was plainly necessary to move to some such refuge. But in truth we are amply helped here, both by the good fortune of our age and by the kind grace of GOD, so that it is ready to hand for us to say what the lunar spots are, or what they can probably be or seem to be — if, that is, we do not wish to declare war on reason, nor to resist the ocular experience acquired from innumerable observations. But if one chose to burst out at once into these words — "why this or that pleased supreme Nature is not within our faculty to know; it is rashness to claim the knowledge of it" — then certainly there would be no further need of any philosophy.

Let these few remarks suffice, whatever has been said, on the various opinions of the philosophers concerning the substance and the spots of the Moon. Their arguments, likewise, have been discussed as far as is sufficient, and shown to carry little weight. For the rest, what is plainly to be judged about the Moon and its spots will be indicated toward the end of this chapter, in which we reject these views. Besides this, we shall touch briefly on the various opinions about the light [lux], the illumination [lumen] and the lighting [illuminatio] of the Moon, and on how the Moon can pour its light back to us and scatter its rays.

[Margin: Various opinions on the light, illumination and lighting of the Moon.]

For we have now sufficiently proved and demonstrated that the Moon possesses no light whatever of its own, innate in it; that it is likewise not diaphanous or transparent; nor indeed is one of its hemispheres perfectly diaphanous, that is, veiled with a certain opacity; nor can its light penetrate to any part of its depth. Rather, it is a body most opaque, most dense, most solid, impervious to all light, and thus dark and murky in itself — indeed such that it borrows all its light from the Sun alone and from nowhere else. In what follows, therefore, we shall also make plain that the Moon does not draw light or rays into itself, nor absorb them, and then, on account of the opacity of its body, pour that light back onto the earth as something infused; rather, it is only light

[Margin: The Moon does not absorb the Sun's light, but, by reason of the opacity of its body, communicates it to us by reflection.]

reflected that it enjoys, and it communicates that light to our earth by reflected rays. That this view is not a new invention is more than sufficiently clear from the fact that Thales of Miletus, Metrodorus, Anaxagoras, Anaximenes and other most ancient philosophers already taught it: that the whole hemisphere of the Moon is illuminated by the Sun, and that the Moon shines of itself in no part. Nearly all the mathematicians of our own age likewise maintain the same.

[Margin: Very many, as also nearly all the mathematicians of our age, agree with this opinion of the ancient philosophers.]

There are indeed authors among the ancients who go the other way — Posidonius, namely, in Macrobius (to say nothing of the rest) — who persuaded themselves that this reflection takes place as if from some mirror, and in this they contradict the opinion of the moderns (as will soon be explained more fully). The view in question is this: that the Moon, like a mirror, sends out again the light it has received from the Sun.

[Margin: Posidonius held that the Moon reflects the solar rays like a mirror.]

But if this is to happen in that way, it will be absolutely necessary first to grant the opacity of the Moon's body, since it is through that opacity that the Moon is fitted to receive and to reflect the light of the Sun — which it could not do unless it were such. And that this is entirely so is amply established also from what has gone before. Further, the surface of the Moon would have to be not only smoothed but also of the most exquisite polish, if it is to present the face of a mirror. Although the matter is arranged quite otherwise, as will appear from what follows, I shall nevertheless grant it for this once, so that it may be seen the more clearly whether this objection [instantia] rests on any solid foundation.

[Margin: The Moon must be smooth and polished if it is to be a mirror.]

If, then, the surface of the Moon presents the true face of a mirror, it must also have some definite figure. For the forms of mirrors are of the most diverse kinds: one is plane; another concave or convex spherical; another concave or convex cylindrical; another concave or convex elliptical, parabolic and hyperbolic, pyramidal, conchoidal or ivy-shaped [Hederaceum]; and, in short, there are as many kinds as there can be lines, or concave or convex surfaces, of a polished body. Although, therefore, the kinds of mirrors are diverse, only some one form out of the three named first can belong to the Moon; the rest by no means suit it, as anyone may gather from its round figure, and from its shadow at the time of solar eclipses.

[Margin: The kinds of mirrors are diverse.]

If, then, anyone should think that the Moon presents the form of a plane mirror — a view to which a great many will perhaps add their vote, especially those who give this matter very little thought, or who are wholly ignorant of optical matters — I shall for this once put before them just two arguments. If they weigh these rightly on the balance of reason, I do not doubt that they will at once recognize that the thing is impossible.

[Margin: Why the Moon does not present the form of a plane mirror.]

In the first place, everyone must admit that as soon as the Sun illuminates any plane surface, at that very moment the whole surface becomes luminous, and it keeps the light equally for as long as the Sun lights that plane with its rays — that is, until the Sun sets on that horizon. Something of the kind would therefore be observed in the Moon if the part of it turned towards us presented a plane mirror. For in that case, right on the first day, when it is imbued with only the thinnest light and appears most horn-shaped, it would show itself to us full of light, and for fourteen days it would be seen with this face entirely

unchanged, until by its own motion it overtook the Sun. Nor, likewise, would any phase be visible about the Moon, nor indeed could it be hidden by the solar rays for three or four days, as is observed at the first phase. Since all these things, one and all, stand otherwise — experience, of course, being witness — it is easily gathered what that fancy [phantasma] of a plane Moon, most like a plane mirror, is worth.

[Margin: If the Moon were a plane mirror, there would be no phases at all; rather, from the very first day of its illumination it would shine with its whole disc.]

But if these reasons should seem to anyone not yet weighty enough, let him know (what no one will be able to deny) the following. Since the exposed part of the Moon is perfectly round as to its circumference, while the rest of its body is flat like a disc [instar orbis], then indeed the hidden part must necessarily consist either of something likewise flat, yet endowed with a definite thickness, as the size of the body indeed requires — and so present the figure of a cylinder — or else the far side presents the appearance of half a sphere, which no doubt, according to their imagining, will also be smoothed and polished, like a convex mirror. Granted, however, that the Moon has whichever of the forms just named they like, yet on that account the aspect of the Moon's face would certainly be wondrous and strange. For since it has been well enough established by me that the Moon is engaged in a perpetual libration,

[Margin: Other reasons why it is not a plane mirror.]

and this will be demonstrated in its place from by far the most certain observations: namely, that the Moon does not perpetually turn one and the same side towards us, but at the proper time also turns towards us no small part of that far face. It would therefore follow that when the Moon, after conjunction, is illuminated by the Sun's rays — especially when it stands at the greatest or the least limit of its libration — first its greatest part, and indeed the whole flat part, would be lit at the same moment, whereas the remaining part, made visible from the far side by the motion of libration, would only gradually, through phases, wax or wane from day to day, as usually happens. Moreover, that flat part would appear not of a perfectly round figure but of an oval form, according to the optical theorem: *A circle seen obliquely appears as an ellipse* (Mersennus [Marin Mersenne], book 1 of the *Optics*, p. 497; d'Aguilon, book 4, prop. 66, p. 286, and book 6, prop. 21, p. 512). Since these things may seem somewhat obscure, I have decided to add these three figures, with whose help the matter will very easily become plain.

[Margin: A circle sometimes appears as an ellipse.]

Diagram. A woodcut of three discs side by side. At left, disc A is solid, shaded with close horizontal hatching. In the middle, circle B has a set of nested crescent arcs along its lower left side, closed at the bottom by a fan of short radiating strokes. At right, circle C carries a matching set of nested crescent arcs along its upper right side, with a fan of radiating strokes at the top. A small cursive engraver's mark stands at the lower right of the block.

- A (centre of the left disc): A
- B (centre of the middle circle): B
- d (upper left of B): d
- g (lower left of B): g
- e (lower right of B): e
- C (centre of the right circle): C
- d (upper left of C): d
- f (right side of C): f
- e (lower right of C): e
- Aut Sc. (lower right of the block, cursive): engraver's mark, *Aut[or] Sc[ulpsit]*, "the author engraved it"

Accordingly, since it is placed beyond all hazard of doubt that the Moon moves with a definite libratory motion about axes (which are seen here at d and e), partly towards the south-east in the order of the signs, partly towards the north-west towards the preceding signs, the face of the Moon can therefore be seen by us in three ways. First, as in A, where it turns the whole flat part towards us; at that time, from the very first day of conjunction right to the last, it will be seen full and perfectly round, as has already been said. Secondly, in B, when, upward towards the north-west, it

[Margin: The foregoing reasons are explained graphically.]

has partly librated itself, it hides a certain part above, but below it offers to our view a small portion of the spherical mirror of the far side, at g. From this it would necessarily follow that, immediately after conjunction, that planisphere B would likewise be wholly illuminated, yet would by no means present a perfectly circular figure from the start, but an ellipse, which would afterwards gradually become the rounder, the more the phases grew from day to day. But before the phases were entirely complete, some small illuminated portion towards the south-east would always be missing, which would change its form or figure from day to day — as is more than sufficiently gathered from these sections representing the phases.

Thirdly, at C, when the Moon, having librated somewhat towards the south-east, appears — namely about the time of conjunction — that spherical part would then be seen on the right. At that time the whole of planisphere C would not be lit at once from the beginning of the illumination; rather, at first it would acquire the Sun's light gradually, through phases, until the Sun fully reached the horizon of that planisphere. Then at last, and indeed in a moment, the whole face of the Moon would be seen full of light for the most part, except for that upper spherical part, which would at first be lit up step by step through phases — as will easily be clear to anyone who carefully inspects and considers this figure placed alongside. The face of the Moon, therefore, is by no means flat, nor can it in any way present a plane mirror.

Even if we were to set aside as well the arguments just adduced — though nothing truer or more certain than they could ever be devised — the impossibility of this falsely conceived opinion nevertheless becomes manifest from what

follows. For since the image of the Sun is never seen in the Moon, as would have to happen by the nature of all mirrors if the Moon too were a mirror, the Moon certainly cannot by any means be a mirror.

[Margin: The author denies that the surface of the Moon is a plane mirror.]

[Margin: Every mirror is fitted to reflect the image [simulachrum] of an object set opposite it.]

I add that the Moon does not present a concave mirror either, which is concluded from the following reasons. For if this were so, the phases would begin to grow immediately after the conjunction [Synodum] of the luminaries not from the right side, that is the western, but from the eastern, left side; since, when the Sun some conca-

[Margin: Why the Moon cannot be a concave mirror either.]

ve one illuminates, the beginning of that illumination occurs in the part facing the Sun, so that the part nearer the Sun is always in shadow at first. This is clearly evident from d'Aguilon, *Optics*, book 4, proposition 94, p. 313, where he says: *"There is this difference: in concave bodies the shadow lies on the same side as that from which the light shines, whereas in convex bodies the dark part is turned away and thrown to the opposite side."* Not to mention that these phases, which would begin to shine from the left side, would soon after the first quarter [Quadraturam] present to us a face entirely different, unusual and strange. But since experience fails us in these things, the Moon certainly cannot be taken for a concave mirror either — to say nothing of the countless other absurdities that would follow from it.

[Margin: How a concave mirror is distinguished from a convex one.]

But if the Moon must nonetheless present the form of some mirror, it will be no other than a convex one; for from what has been said above it is now plainly established that the face of the Moon can be neither plane nor concave, as its manner of receiving the Sun's light confirms. Now, so that this discussion may be the better understood by anyone, even one little practised in optics — namely, that the face of the Moon is not a convex mirror either, although beyond all doubt it is of globular figure — I shall first set out certain catoptric theorems, which I also mentioned in part in the second chapter; at the same time we shall briefly consider the nature and quality of mirrors, above all so that we may understand how the forms of visible species become perceptible to us from mirrors.

[Margin: The Moon does not present a convex mirror either.]

I. *The surfaces of clean, polished bodies, of whatever figure they may be, reflect from any of their points the lights, colours and forms of things set opposite them, along straight lines.* (Witelo, book 5, theorem 1, p. 191; Ibn al-Haytham 4, no. 2; Maurolycus, theorem 25; Euclid, *Catoptrics*, hypothesis 2.)

[Margin: First catoptric theorem.]

II. *In every reflection, made by whatever mirrors, the angle of incidence is always equal to the angle of reflection.* (Witelo, book 5, theorems 10, 12 and 20, etc.;

Ibn al-Haytham, book 4, nos. 10, 12 and 18; Maurolycus, theorems 27 and 29; Antonius de Dominis [Marco Antonio de Dominis], chapter 2, p. 3.)

[Margin: Second catoptric theorem.]

III. *Reflection alone — the reflection that reaches the sight — brings about the perception of visible forms in a mirror; hence the sight is necessarily informed according to the disposition of the lines of reflection. That is: every reflection is seen in at least one place, and under a definite angle of inclination.* (Witelo, book 5, theorems 23 and 24; Ibn al-Haytham 4, no. 21; Antonius de Dominis, chapter 2, no. 8.)

[Margin: Third catoptric theorem.]

Since these theorems are altogether and indubitably true, so that

they cannot be shaken by anyone in his right mind, let alone overturned, it necessarily follows that the Moon, as a mirror, could be perceived at only one single definite place on Earth, and not wherever in the world it has risen above the horizon — by reason, that is, of the angle of incidence and reflection; for to all other places it would be altogether invisible.

[Margin: Plane mirrors throw their reflection to one place only, but convex ones in every direction.]

Suppose, however, someone objects that he indeed grants, without any contradiction, all the things I have put forward; but that, since the surface of the Moon presents a convex mirror, its surface accordingly consists of an infinity of inclinations, by reason of which the Moon throws its reflection to all parts in every direction, and not, as happens with plane mirrors, to one place only. To this I reply, first: since the Moon's hemisphere, outside full moon, is never wholly illuminated by the Sun with respect to the Earth — especially in the sickle-shaped and horned phases — therefore even by means of that infinity of inclinations, which indeed arises from the whole surface, the rays are not reflected to any part whatever, but only to a definite place, except, as I mentioned above, at the time of full moon. And even if these things are granted, nothing else will follow from them than that, at every place in all parts, the image of the Sun alone would be seen by means of that convex mirror — and indeed much smaller than the apparent face of the Sun. For convex mirrors render all objects and images [idola] smaller than they really are, as is evident from that catoptric theorem: *In convex mirrors the images are smaller* (Herigon [Pierre Hérigone], proposition 22, p. 111).

[Margin: Spherical mirrors render the images [simulachra] of all things set opposite them smaller.]

But suppose you meet this objection thus: that it is not necessary for images of the Sun to be seen in the Moon's convex mirror, since because of that excessive distance they would vanish entirely — in accordance with that optical principle in d'Aguilon, book 5, p. 420: *Convex mirrors show things much smaller than they actually are, and the images are diminished the more, the farther the things themselves stand from the mirror* (Witelo, book 6, no. 41; Ibn al-Haytham, book 6, no. 5, p. 190). Mersenne too speaks in the same way in Catoptric Theorem 1, p. 505: *In convex mirrors left appears right, and the image lies nearer to the mirror*

than the visible object, and is smaller; and the smaller, the smaller the mirror is; but the larger, the nearer the visible object is. All these things I embrace with both hands, since they are most certain, and I shall myself use them as a foun-

[Margin: The farther a thing is from a convex mirror, the more it is diminished.]

[Margin: The smaller a convex mirror is, and the more remote the object, the smaller too is the object represented by the mirror.]

dation on which I shall presently build something, so that the contrary may be demonstrated from them and infallibly concluded: that the surface of the Moon is by no means convex.

First, then: for some object to appear luminous to us, it is not enough that it be struck by the rays of an illuminating body; it is further required that the reflected rays reach our eye. Therefore, since only a very small part of the reflection of rays made by some illuminated convex mirror falls into the eyes of a given spectator (for that particle of the whole spherical surface whose inclination throws the ray back to a definite place of the eye is very small, as Galileo says most elegantly on this matter in his *Systema Cosmicum*), it must certainly also be a very small part of the spherical surface that shows itself shining to the eye, all the others remaining dark. Hence we see nothing at all of the remaining part, although the whole surface faces the Sun — not only because of the fewness of the rays, but also because of the excessive distance, by which these rays, reflected from that very small particle of the surface of the convex spherical mirror whose inclination would permit it, would be entirely absorbed.

[Margin: From a convex mirror very few reflected rays are brought to a given spectator.]

It would be the same with the Moon if it had the smoothness of a convex mirror: a very small part would cast the Sun's splendour into the eyes of a given spectator, even though the whole hemisphere were exposed to the Sun's rays; but the remaining part would appear to the spectator's eye as not illuminated, and therefore not visible either; and in the end the Moon itself would appear wholly invisible, since that particle from which the reflection would proceed must vanish because of its smallness and the excessive distance. And just as the Moon would be invisible to the eye, so its illumination would come to nothing.

[Margin: The Moon, if it were like a spherical mirror, would be invisible.]

For the rest, I am entirely of the same opinion as d'Aguilon: that even if someone were standing next to the Moon, the Sun's image would not appear to him even like the tiniest little star, because of that immense distance; indeed, that at the midpoint of the Sun's elongation from the Earth that very small image of it would vanish altogether before it could reach us. This argument — namely, that the surface of the Moon is not smoothed or polished like a convex mirror — is so strong that no one could even assail it, so far is it from being possible to overthrow and undermine it: unless perhaps those people, to undertake it

[Margin: If the Moon were a spherical mirror, the image of the Sun would appear like a very tiny little star.]

over-confidently dare — people who have scarcely greeted optics and catoptrics from the threshold.

Finally, then, the question is pressed with the greatest anxiety. The surface of the Moon is neither a convex mirror, nor a concave one, nor a plane one, as was abundantly demonstrated above; and yet the Moon is a most opaque body, which merely borrows its light from the Sun and transfers that same light to us by means of reflection. With what figure, then, is its surface endowed, and how does it pour its rays out onto the Earth?

[Margin: The question asked: with what surface is the Moon endowed?]

I answer: the spherical surface of the Moon is by no means plane, smoothed or polished, but altogether uneven, rough and most rugged; and yet, this notwithstanding, it offers us its rays by reflection, and indeed in exactly the way in which any wall turned towards us communicates the Sun's light. For it is not at once required that all things which must act by reflection be plane and polished like a mirror. That this is entirely so will soon become clear from what follows.

[Margin: The Moon's surface is altogether rough and rugged, and nevertheless communicates light to us by reflection.]

[Margin: Not all things that act by reflection need be polished bodies.]

But lest anyone think that what I have related is either the fictions of men awake or the dreams of men asleep, I ask him to weigh the following passages from Plutarch's book *On the Face in the Orb of the Moon* [de facie in orbe Lunæ], p. 310, which will be set down word for word, and to turn them over well in his mind: he will learn that the same things were laid down many centuries ago. "The Moon," says that librarian of nature and of every kind of ancient learning, "has many inequalities, many roughnesses, so that the flashes that arise from a great body can shine back on one another from heights of no small size, and be reflected in every way, be interwoven, and carry their brightness on among themselves, as though it were being carried to us from many mirrors." In the same author these words also stand, on p. 316: "As to the face that appears in the Moon: just as our Earth has certain great gulfs, so we judge that the Moon too is opened up by great depths and fissures containing water or murky air. Into these the Sun does not penetrate with its light, but, abandoning them, makes the reflection dispersed." Very many of the Greek philosophers were likewise devoted to this opinion, such as Democritus, Orpheus, Heraclides, Ocellus and others, as Franciscus Patritius reports in his *Nova Philosophia de Universis*, book 20, p. 112.

[Margin: That mountains and valleys and roughnesses exist on the Moon is shown to be a very ancient opinion.]

But I shall turn to proving that the Moon, being uneven and rough, communicates to us the Sun's borrowed light just like any wall lit by the Sun. For, in the first place, this

[Margin: The Moon communicates light just like a wall lit by the Sun.]

is attested by daily experience. If you look at some mirror next to a wall lit by the Sun, you will soon notice that the rough and rugged wall reflects a greater light (more universal, I think, not stronger) into all the parts opposite it — a light, moreover, that is even, pleasant and bearable, and that anyone can view equally well from any station whatever. The mirror, on the contrary, appears much darker, except at one single definite place, which its rays reach by way of the angle of incidence and of reflection. You will also find that the light is never greater than the mirror itself, and that it is seen by no one other than the person who occupies that place. Moreover, the light reflected from the mirror is extremely vehement, unbearable, and hurts the sight; this in no way agrees with the light of the Moon, since the Moon's light, like a wall's, is universal, pleasant and weak.

[Margin: A rugged wall, when illuminated, reflects light in every direction more universally than a mirror.]

The reason why the surface of that wall, so rugged, uneven and rough, is able to produce or reflect such a universal light is this. Since that surface is rough and uneven everywhere, it is by that very fact also composed of innumerable minute surfaces, disposed according to an innumerable diversity of inclinations (as Galileo ingeniously puts it in his *System*). Among these it necessarily happens that many are disposed to send reflected rays from themselves to this place, and many others to another; in sum, there is no place that very many reflected rays do not reach from very many little surfaces dispersed over the whole surface of the rugged body struck by the luminous rays. Hence it follows by a definite law that reflected rays — and consequently illumination as well — reach any part whatever that is set opposite any surface whatever receiving the primary incident rays. It also follows that the body itself on which the illuminating rays fall appears wholly illuminated and bright, seen from any place whatever. Therefore the Moon, having a rough and not a smooth surface, must diffuse the Sun's light in every direction and show herself equally bright to all her spectators. But if the surface of the Moon were of perfect sphericity, and its figure supremely well turned, as Aristotle says, smoothed like a mirror,

[Margin: How can the rugged surface of a wall produce so universal a light?]

[Margin: Since the Moon's surface is extremely full of swellings and hollows, she therefore shows herself equally luminous to everyone at any time and place.]

it would remain altogether invisible, as has already been said above. From these and other reasons, therefore, it becomes plain that the Moon's surface is by no means smooth or polished, but altogether rough and rugged. The same can be proved from the *Optics* of François d'Aguilon, book 3, proposition 20 (although he, indeed, wished to have nothing in common with our opinion), and especially from the passage where he teaches how a smooth body and a rough one can be told apart. "If," he says, "no reflection of light or of images occurs, in whatever position the thing is finally turned towards the eyes, the sight will judge it to be rough. For if it were smooth and highly polished, it

would send light and the forms of things back from itself to the eyes of the beholder in at least some opposite position."

[Margin: How a rough body can be distinguished from a smooth one.]

And even if all this were unknown, what we want can moreover be proved without difficulty and plainly demonstrated from those gilded spheres and globes that are commonly seen on towers or on the tops of buildings and churches. For the more polished and clean they are, the less of them is seen when they are lit by the Sun; but the rougher they are, the better they are seen, even though they are far smaller, and they spread a more universal light from themselves than the others, which are more polished. The same is confirmed more and more, and altogether, by comparing all polished spheres (whether they are made of metal, glass, marble or some other not dissimilar material) with some rough sphere full of hollows and swellings, if they are exposed together to the Sun, or to some other light, at one and the same distance.

[Margin: Spherical bodies, the rougher they are, spread light from themselves the more universally.]

Since, then, from what has been said it is at last established abundantly enough that the Moon's surface is uneven and rough, it remains for me to demonstrate also that this roughness is nothing other than, in reality, mountains, valleys, lakes, seas, bays, promontories, continents and the like; that in those lunar oceans there exist partly islands girded round with steep mountains, and partly also islands free of mountains on every side; and further, that here and there towering cliffs, marshes and pools are observed, and very many other things which are certainly not unable to be compared, and not unfittingly, with our things on Earth.

[Margin: The swollen and hollowed parts of the Moon are mountains and valleys.]

On this account, indeed, we who have been reserved for this age judge, not undeservedly, that we are much more fortunate than all the rest of our predecessors, since Fortune, or rather

[Margin: That we are more fortunate than our ancestors.]

God, thrice Best and Greatest, in his clemency and by his divine will, has opened and laid open to us a far shorter and surer way of philosophizing, especially in matters of astronomy and those concerning the heavenly bodies. For it has been granted to us to philosophize not only through reasonings but also through the senses themselves, above all through the noblest of them, the eye — not, indeed, the naked eye, but the armed one — and, as it were, to touch the thing with a needle's point: armed, I say, with the telescope, which can never be extolled enough by the words and praises of all. By its benefit we are brought thirty or forty times nearer to the heavens than our predecessors have been until now, so that not only are our eyes made that many times sharper, but those ethereal bodies, so immensely far removed, are also shown to us much larger. In this way, at last, we have also been able to detect in those heavenly

bodies many wonderful things formerly unknown, which could come into no one's mind in an earlier age; some of these have already been mentioned.

[Margin: By the aid of the telescope we are now brought thirty or forty times nearer to the heavens.]

Among the other memorable things we have noticed not long ago, one certainly holds by no means the lowest place (to pass over very many other things most worth knowing, which can bring the greatest benefit not only to astronomy and geography but also to navigation — something we shall take care to treat more fully in its proper place): namely, that the constitution of the body of the Moon and of its spots, which are visible partly to the naked eye and partly to the armed eye, has now for the first time been correctly observed and thoroughly explored by us. On this matter those ancients, philosophers and astronomers alike, since they were guided only by their own thoughts and speculations, sowed such great quarrels and wrangling among themselves that they could not get out of them, much less establish anything certain. Because this was related above, we do not wish now to do over what has already been done by explaining it again.

[Margin: Before the invention of the tube-spectacles, no one ever correctly understood the Moon's spots.]

But after we had looked out with our eyes through the telescope a few years ago, we discovered, with certainly no great labour, that those brighter parts of the Moon can be compared to land, and its smaller spots to mountains and valleys; but that the larger spots, which present a certain appearance, can be compared with nothing more fittingly than with our earthly seas, oceans, lakes and so on. Of these I have resolved, with God's help, to treat briefly and in general on this occasion, and later more fully and in particular.

[Margin: With which earthly things the bright and dark parts of the Moon may fittingly be compared.]

How, then, together with not a few others who share the same view, we were driven to establish and decide such things will have to be related in order — above all so that it may at the same time be plain that we were compelled to take up this opinion not out of some inclination to contrive novelties, but by the force of weighty and pressing reasons. For, as Marius Bettinus [Mario Bettini] says (*Apiaria* 8, Progymnasma 6, proposition 1), *it is consonant with reason, and necessary, that astronomers who philosophize properly should assert that nothing, and especially nothing new, is found in the heavenly bodies, unless some reason, especially one drawn from the phenomena, compels them to assert those new entities on high.*

[Margin: Nothing new is to be established in the heavens unless definite phenomena compel it.]

First, then, we saw and observed, well and distinctly, by the benefit of the spyglass already praised, that the sections of light and shadow, in the waxing as well as in the waning Moon, are winding, toothed and rough. Next, we saw that beyond that boundary, in the dark and least illuminated part, bright

little areas [areolae] are visible here and there — varied, some tiny and some fairly large, extremely diverse in form, and standing no small distance from the boundary between the illuminated and the shadowed part. Likewise, we saw that there are other little areas, adhering to the illuminated part, which gradually change and vary their form and shape as the light grows, until they are joined on every side to the illuminated part and are completely suffused with light along with the nearer edges; and that soon very many new ones again rise in that dark part and take the place of the preceding ones. The contrary happens in the waning phases of the Moon: there the little areas that now adhere to the boundary and to the illuminated part are gradually torn away and are seen luminous for longer, just as, when the Moon is waxing, they are illuminated sooner than the other, lower places lying around them. All the lunar figures bear witness to this.

[Margin: By what reasons were we compelled to assert certain novelties in the heavens?]

[Margin: The boundary between the light and the shadowed part of the Moon is very winding and rough.]

[Margin: Brighter points flash out here and there in the dark part of the Moon.]

From this phenomenon, therefore, we could conclude nothing other than that the Moon is very rough and crammed on every side with steep mountains and very deep valleys. For if the lunar body were smooth and of a figure of the most perfect roundness, that section of the bright and the dark part would certainly be seen as nothing other than exquisitely even, smooth and free of all roughness — as is made manifest by a perfectly round and polished globe. As for those brighter points that flash out beyond the boundary of the light, they are nothing but the points and summits

[Margin: Why is the surface of the Moon not entirely smooth?]

[Margin: The brighter little areas visible beyond the boundary are the ridges of the loftier mountains]

of very lofty mountains. Since these are higher than the other, lower places nearby, they can for that reason also be illuminated by the Sun sooner. This would otherwise be impossible if there were no mountains and valleys and protruding parts on the Moon, but all its parts were illuminated at once; and beyond the section of illumination no little areas at all would ever be seen. Indeed, one can see this happen every day at sunrise around our own higher mountains, towers and the tops of buildings. For it comes about, before the Sun rises, that those mountains and towers are bathed in its light the sooner, the higher they reach up. Then, as the Sun gradually ascends, it illuminates little by little, more and more, the adjacent lower places as well, each according to its height; and finally, when it is raised higher above the horizon, it illuminates the continents and all the remaining lower parts, except the valleys that are enclosed by mountains on every side.

[Margin: The rising Sun illuminates the higher mountains and towers before the sloping places.]

For the valleys, even though the Sun grazes the horizon, enjoy no light at all, because the mountains that surround them shut out the Sun's rays, so that a very great shadow is produced in those valleys; and it is the darker, the higher the hills and mountains rise. But when the Sun is higher, they take in more light: first the mountains of the valleys that face the Sun are illuminated, then the more sloping places of the mountains and the plains adjoining them. And the more the Sun is lifted up, the more the shadow of the valleys contracts and becomes shorter, while the level ground is more strongly lit and becomes brighter — until the Sun reaches the vertical point. At that time it illuminates the whole valley, the shadow vanishing completely, and the valleys already mentioned are just as bright as the summits of the mountains; indeed, because of the varied reflection of the Sun's rays, they present themselves to the gaze as much brighter than these.

[Margin: How are valleys illuminated?]

[Margin: When the Sun stands vertically over them, valleys are illuminated as brightly as the summits of mountains.]

But it is different again when the Sun is going down towards its setting: the valleys (if they are walled round by mountains on every side) are gradually darkened by the shadows of the mountains. Here it must be noted that this darkening now occurs not from the left side but from the right, the directly opposite one; for when the Sun changes its quarter of the sky, the shadow too must vary. Afterwards, the further the Sun descends, the longer the shadows and the darker the valleys become; and when at last it has entirely set, only the summits of the higher mountains and towers are lit by the Sun's rays.

These things I have wished to explain so fully and distinctly in order that hereafter I may the more easily draw a comparison between the lunar mountains and valleys and these terrestrial parts of ours; and also so that I may set out and hand down to all students of selenography, the more clearly and explicitly, the nature, essence and quality of all of them. But let us return once more to the observations themselves, and review what else has been noticed on the Moon.

[Margin: Lunar spots surrounded by very bright circles change their colours.]

Among other things, smaller, blacker spots of varying size, surrounded by very bright circles, have been observed in the phases of the Moon both waxing and waning. In their colour [recte: colorem] these are very rarely like one another, and they appear not only near or right at the boundary [confinium] but also throughout the whole illuminated part of the Moon (here I do not mean those large spots visible to the naked eye, of which more hereafter), as is plainly discovered from all the figures of the phases [Iconismi].

[Margin: These bright circles are the summits of mountains.]

That these spots are nothing other than valleys clothed all round with steep, rather lofty and very dense mountains, I was able to gather from the following reasons.

[Margin: By which appearances and reasons we are persuaded that mountains and valleys exist on the Moon.]

First, because the valleys (if I may call them so, although this has not yet been demonstrated), when they stand on the very section of light and shadow [Sectio lucis et umbrae] or near it, have always been found extremely dark and full of shadow. Phases 11, 12, 14, 26, 27, 28, 30 and 31 in particular show this to the eye, and others show the same as well.

Second, because the further the valleys recede from the boundary while the Moon is waxing, the greater the light they are bathed in, in the manner of terrestrial valleys: so that the shadow decreases day by day and becomes shorter, narrower and thinner, according to the greater distance of the Moon from the Sun, or the higher position of the Sun. And when the Moon reaches the vertical point — that is, at the time of full Moon — the valleys just mentioned are entirely illuminated, and although they were black and extremely dark, they become very bright.

Third, because soon after opposition, when the Moon begins to wane and the Sun to recede from the vertical circle and to sink towards the western horizon, the shadow arises again in all these valleys and hollows in the usual manner and order — except that the shadow changes its place and moves to the other side.

These, then, are the chief reasons that moved us to posit protruding parts on the Moon — mountains and valleys. First (as has been heard), that serrated, twisting and winding line of the section of the illuminated part; 2. the very bright small areas [areolae] standing outside the boundary, or the Moon's horizon; 3. the manner in which these mountains and valleys are illuminated; 4. finally, the nature of the shadow.

[Margin: It is proved from optics that these reasons are sure and undoubted arguments for telling a rugged body from a smooth one.]

But so that you may be equally certain that these reasons are founded no less in optics than in nature, I shall in addition bring forward certain infallible indications and arguments that have been supplied to us for recognising, rightly and properly, a body that is rough and uneven and heaped with mountains and valleys. For I hope it will not be unwelcome if I demonstrate this more fully from sure optical foundations. Our first two reasons can be established on the testimony of d'Aguilon, *Optics*, book 3, proposition 20, page 170, since he says: *"A marked roughness can be recognised from the light with which the projecting parts are bathed: for if these alone shine out when lit up, while the depths appear dark, it will be beyond doubt evidence of a perceptible roughness."*

[Margin: Projections are recognised from shadows.]

The third reason is likewise corroborated from d'Aguilon, book 3, proposition 19, page 170: *"Projecting bosses,"* he says, *"cast shadows into the hollow depressions; from these, therefore, sight gathers that those parts which are rough are deep, and that those are higher which send brightness back to the eyes from the light*

with which they are bathed. The position of the body helps towards this very recognition — namely if it is set obliquely to the light; for in this way the deep parts receive shadows more abundantly, etc." This is just what usually happens when cavities are seen on or near the line of the section of light and shadow.

The fourth reason, which concerns the shadow and its nature, is confirmed beyond doubt by several optical theorems, as follows. 1. Cavities and valleys can be recognised most perfectly with the help of shadow; Mersenne attests this in his *Optics*, theorem 8, page 494: *"Sight distinguishes the projections and depths of bodies above all from their shadows."*

[Margin: The shadow falls towards the side opposite the light.]

2. *"An opaque body casts its shadow towards the side opposite the light."* D'Aguilon, book 5, proposition 60, page 424, and Rhodius, book 1, chapter 3, proposition 25. 3. *"The shadow is sometimes equal to its opaque body, sometimes shorter, sometimes longer, according to the differing height of the luminous body."* Rhodius, book 1, chapter 3, proposition 33, and book 1, chapter 3, proposition 31.

[Margin: The shadow varies with the position of the opaque body and of the luminous one.]

4. *"The shadow imitates the shape and motion of the opaque body, although it can also be moved by the motion of the luminous body alone; but if it is moved around the opaque body, the shadow will be driven with contrary motions, and at an equal speed."* Mersenne, theorem 23, page 484.

If, therefore, these things — as also all those which, for the confirmation of the lunar mountains and valleys I have set out above — are properly weighed, examined by the right rule of reason and compared with these optical theorems, above all by someone who is not wholly unversed in optical matters, it will easily be judged that all of them have been demonstrated plainly and most truly, and by sure and infallible arguments. But if such things are hard for anyone to grasp and understand, I send him on to what follows, where more will be said on this subject.

[Margin: François d'Aguilon and Mario Bettini by no means grant mountains and valleys on the Moon.]

Meanwhile, however, one or two of the philosophers are found — to say nothing of the rest — namely the excellent François d'Aguilon and, above all, the most learned Father Mario Bettini, a vehement Peripatetic, who by no means embrace this opinion. In Bettini, in the *Apiaria* 8, Pro. 6, propositions 1, 2 and 3, one may read various reasons for which he holds that what we have said cannot be so. I admit that at first sight these carry a great appearance of truth, so that I do not doubt they may perhaps give a good deal of trouble to someone not thoroughly acquainted with these matters. Let us therefore weigh them in order and examine them properly, so that the truth may shine out all the more — and this above all for the sake of the Peripatetics, *who for the most part, against clear demonstrations of the truth, nonetheless fortify themselves with the ambitious authority of Aristotle, in which they place such security for their knowledge*

that they even pledge the whole of nature on his word, as Johannes Fabricius says in his observation on the solar spots [de Macul. Solar.].

[Margin: The Peripatetics for the most part prefer the authority of Aristotle to apodictic demonstrations.]

[Margin: Bettini's arguments are examined.]

Bettini, just named, does indeed grant this — being, as is clear from his great work, a most practised optician — and he says that he himself observed that at the time of quadrature the boundary of light and shadow is very winding, rough and toothed, so that it shows here and there, in the dark part of the Moon, very bright small areas outside the section, like many islands standing out in a vast ocean of darkness; and that these are then bathed little by little more and more in light, until from islands they become, as it were, peninsulas, and are joined by continuous light to the larger body — that is, to the rest of the illuminated body. But he soon adds that it is not necessary to posit mountains and valleys at once on the strength of this phenomenon, since even with these removed, all those things can happen and occur to our sight through the opti-

[Margin: Bettini tries to remove mountains and valleys from the Moon by means of rarer and denser parts.]

cal tube, even if you assert that the Moon is altogether smooth and round — provided only that rarer, transparent parts and denser parts are supposed in it. The author's words are these: *"And accordingly, when the lunar globe is breathed upon by the solar rays, the denser parts (whose summits reach the outermost compass of the lunar sphere, and between which some rarer and transparent parts are interposed), because by their density they terminate the light, which the rarer parts do not terminate, therefore, although posterior in position, nevertheless appear prior and anterior in illumination."* So he.

[Margin: The author's reply.]

To this I reply that I cannot wonder enough that Bettini, after he had clearly seen through the telescope [Tuboſpicilli] that the boundary of light is winding, and also that very many luminous points shine out beyond it — namely in the part of the Moon not yet steeped in the Sun's [phœbeo] light — did not at the same time also see those various darker spots, namely the concavities and caverns, standing out in the illuminated part. For the tube that had revealed the former phenomena is presumed to have shown this last one too; but perhaps he deliberately chose not to look at them. Indeed, had he observed them continuously over some interval of time, I have no doubt that they would at once have left him wavering. For he would have noticed how, near the boundary, these spots showed themselves wholly dark, that is, full of shadows; how a little later, as the Moon waxed, the shadow on the right side, toward the Sun, decreased little by little day by day, indeed hour by hour, and grew shorter and thinner in proportion to the Moon's greater distance from the Sun; how, on the contrary, the valleys grew brighter day by day, so that around full Moon they enjoyed the greatest light — those very valleys which before had been extremely dark and had shared in no light whatever. And after opposition,

he would have noticed how the shadow pushed itself again from the left side, as seen by us, into those concavities, and, growing over those places more and more each day and extending itself, made them darker, until the caverns around the boundary itself are again darkened on every side — except that a certain bright circle remains all round them, namely the illuminated ridges of the very high mountains that form the valley.

But I am also most eager to know what any Peripatetic, however far the most learned of them, would reply to this, and in what way the changes of these spots and concavities, from light and

shadow as they arise, he would care to square with his rarer and denser parts — even if everything Mario Bettini objects were conceded, although I have already amply demonstrated above that the matter stands otherwise.

[Margin: What are the rarer and denser parts?]

For tell me, please, according to your own opinion and pleasure: what are the rarer and the denser parts? Beyond all doubt you will say, with Father Bettini, that the rarer parts are those which by their rarity do not terminate the light, and so cause some rays to be reflected and some refracted, with the result that they necessarily cannot be seen as so bright and clear; whereas the denser parts are those which by their density terminate the light, so that the rays are only reflected — and for this reason they also look whiter and more illuminated, as can be accurately demonstrated from optics.

[Margin: Denser and rarer parts do not vary the appearance of the light.]

This I readily grant, and I am myself wholly of the opinion that it cannot be otherwise. It therefore necessarily follows that the rarer parts cannot appear clear or bright, and the denser parts by no means dark and blackish; and further, that whatever once looks dark and murky will never look clear and bright.

[Margin: Since certain spots appear now bright, now dark, they therefore cannot be rarer or denser parts.]

This being so, I ask further — like any man from the street-corner — how it comes about that the blackness or darkness of the spots seen within the limit of light varies from day to day, indeed from hour to hour, and does so according to the distance of the Moon and the Sun, or rather according to the altitude of the Sun with respect to the Moon? Further, why are the spots the clearer and brighter the nearer the Moon is to opposition — indeed, why, around the opposition of the luminaries, are they seen wholly steeped in all light (as all my lunar figures [Iconiſmi Lunares], to the last one, indeed demonstrate; and whoever finds these not yet sufficient, let him make the test himself with some excellent tube, and I have no doubt he will observe that everything is so)? And why, after opposition, do they gradually become blacker and darker again? If they are once rarer parts when they stand near the section of light and shadow, how then, on the other occasion, around full Moon, will they be denser parts, since they appear wholly and most brightly lit, as the experience of the eyes bears witness? Whether these are not contradictories, opposed to each other

diametrically, I leave to the fair judgement of the reader. Indeed, certainly no one can judge of this matter otherwise than that impos-

[Margin: If anyone can explain all the phenomena of the Moon by rarer and denser parts, the author promises that he will become an adherent of the Peripatetic sect.]

sible things are laid down here, which can in no way exist. Moreover, if anyone comes forward who can reconcile this phenomenon with rarer and denser parts in such a way that they plainly answer to our observations in every respect, I openly declare here that I will indeed go over to the camp of the Peripatetics. This much I wished to reply to the first objection [inſtantiam] of Father Mario Bettini.

[Margin: Reply to Bettini's second objection.]

As for the second, where he says: *"Since there are no phenomena on the periphery of the Moon — neither traces of parts standing out beyond others, nor of denser and rarer parts, contiguous or continuous — we therefore deny that there are dissimilar parts in it, and consequently also mountains on the face of the Moon"* (*Apiaria* 8, Progym. 6, prop. 2). With these words he meant to indicate briefly not only that there are no eminences on the periphery, but also, indirectly, to deny all mountains, valleys and concavities in the rest of the Moon. For, he continues, if they must be granted in any way on the periphery itself, it is necessary that they appear near full Moon, whether it is about to come or has just passed.

[Margin: Bettini thinks that no mountains can ever be seen on the periphery itself.]

"But," he says, *"they are not seen on the periphery, nor are they ever put forward as observed by our opponents, and much less ought they to be put forward when the Moon is between the eye and the Sun; for that they are seen at that time, whether on the face or on the periphery of the Moon, is false and impossible, for the reasons already given."*

If these things were beyond doubt and plainly true, I would certainly be so unwilling to fight against shining truth that I would rather concede him the victory of my own accord. It must indeed be admitted that up to now no one has noticed such brighter small areas beyond the boundary of the light and the shadowy part, either a little before or a little after full Moon — much less that the periphery itself was ever observed to be rough and uneven at that time, as Galileo Galilei testifies in the *Sidereus Nuncius* [Nunc. Sider.], page 20. I suppose, therefore, that anyone reading this will readily conclude that it is vain to posit mountains and valleys on the Moon.

[Margin: The author has many times, at the time of full Moon, seen eminences on the periphery itself.]

But truly — make haste slowly, kind reader, and suspend your judgement a little: you will receive from me things more certain, however unheard of. I have, namely, very often observed such phenomena at the most varied times, both a little before and a little after opposition — indeed (which deserves greater wonder) on the very day of full Moon, and even at the very moment of

opposition. And so that I may not seem to confirm this by words alone, I shall bring forward some observations out of many.

[Margin: … is proved by observations.]

1. In the phase of the Mature Moon [Lunæ Adultæ], observed in 1644 January 21, four notable brighter small areas, or illuminated mountain peaks, are seen beyond the section of the luminous part, adhering to the eastern periphery: three, namely, in the middle, and one higher up, towards the top. Moreover, the whole boundary is seen to be quite rough and uneven, except only in that one place where it cuts across a certain large spot — a sea, namely. This could not have happened otherwise, as will be explained towards the end of this chapter.

[Margin: First observation.]

2. In the nineteenth phase, of the Moon verging towards opposition, in 1644 January 22, on the very first day after the true full Moon, the western periphery likewise appeared not a little jagged.

[Margin: Second observation.]

3. In the Moon's 22nd face, drawn in 1643 November 26, as also in the twenty-third, delineated in 1643 November 27, not only was the western periphery noted as toothed and winding, but very many bright points were noted as well.

[Margin: Third observation.]

But perhaps you will retort: such things have indeed been observed and noticed on the first or second day before or after opposition, but not on the very day of that aspect? To meet this objection too, I shall therefore mention certain other remarkable observations, of a kind that scarcely anyone has made up to now (though I would not wish this to be said arrogantly). I have, namely, sometimes seen the face of the Moon, even at the time of true opposition, completely full and bounded not by an entirely smooth periphery, but with one side of it quite rough. Sometimes, too, illuminated points, very bright, standing some distance outside the periphery, have been clearly seen. This roughness was visible not only on the western or eastern limb but, at a certain time, also on the southern or northern limb. I ask that this be well noted: for once this phenomenon is attended to, many things unknown and very difficult to understand can henceforth be understood and explained, as will be shown in its proper place and time.

[Margin: The author has noticed roughness of the lunar periphery, in the southern as well as the northern part.]

A notable example of this kind presented itself to me in 1644 January 23, at the seventh hour of the evening, the fourth before the true full Moon; at which time the periphery of the Moon seemed almost

[Margin: Fourth observation.]

rounded, except that on the eastern margin two eminences and small areas were still conspicuous. At the fourth hour from then, however — namely at the time of true opposition, at the tenth hour of the evening — the limb

verging towards the east was now entirely even and smooth; in turn, a notable roughness had again invaded the northern margin, although a certain decrease ought rather to have been seen on the western side.

[Margin: Fifth observation.]

A similar, excellent example was observed by us in 1644 March 23, at the seventh hour of the evening, the ninth after the exact aspect of the luminaries. On the periphery facing the west nothing whatever had yet waned, as it rightly should have; but the southern limb was in no moderate degree rough and uneven, and this roughness affected almost a fifth part of the surface. About the middle, outside the periphery — though they clung almost tightly to it — two tiny, very bright, arched particles were seen, as if they were the peaks of mountains. We are surely right to wonder that roughness of this kind could be seen at the very full Moon, or even a little after, and indeed on an entirely different side from the one it should have been on. This unevenness of the periphery was still noticed at the twelfth hour counted from noon, although it was gradually decreasing and becoming flatter; by contrast, the roughness of the limb facing the east [Subſolanum] was gradually growing.

From these examples (to say nothing of others, which we reserve for a more suitable place) it can be seen more than enough that not only are certain brighter small areas conspicuous on the very periphery of the Moon and outside it, both a little before and a little after opposition, but also that phenomena of this kind appear no less on the same day, and indeed at the time of true opposition. These are certainly nothing other than the peaks and summits of lofty mountains standing there.

[Margin: By inverting Bettini's argument, the contrary is proved.]

Since, then, Father Mario Bettini, in his *Apiaria* 8, Progymn. 6, prop. 2, last §, reasons in this way: "Since on the periphery of the Moon around full Moon no roughness and unevenness is indeed noticed, nor is any ever put forward as observed by anyone, we therefore in no way grant mountains and valleys on the periphery, and consequently not in any other part of the Moon either" — I invert this argument, and argue against him thus: since

phenomena on the periphery of the Moon, or very many traces of parts standing out beyond others, have often been observed by us, both a little before or after full Moon and at the time of true opposition, it must be concluded that there are parts standing out above others — that is, mountains and valleys, both on the periphery itself and on the whole remaining lunar surface.

[Margin: By another infallible argument it is demonstrated that mountains stand out on the very limb of the Moon.]

Although this one argument would suffice to demonstrate the things already mentioned, I shall nevertheless bring forward yet another, by which it will likewise be proved beyond doubt that mountains and valleys do indeed stand out on the lunar periphery, and at the same time are visible to anyone who refuses to credit the matter. This is suggested to us by the motion of libration. For it is certain — as will also be shown clearly by us later — that the Moon does

not at all times present one and the same face for us to see (although very many astronomers, ancient as well as more recent, have held the contrary), but that at a certain time, by reason of this libration, it moves not a little about its axes; so much so that a by no means small part is uncovered to us, sometimes towards the west [Favonium] and north, sometimes towards the east and south. (This is clearly perceived from those three great lunar figures [Iconismi] of the full Moons, which express this motion of libration of the disc, already mentioned, by two different circles or limbs; the space lying between the two circles of the Moon is the part that is seen on the front side of the Moon at a given time.)

[Margin: The Moon is subject to a certain librating motion.]

[Margin: The librating part of the Moon is enclosed by the two circles of the lunar figures of the full Moons.]

Hence it comes about that when the outermost circle on the west represents the periphery of the Moon, the Palus Mæotis stands very far from it; but when the nearest limb describes the Moon's periphery, the same Palus lies very close to it. The contrary happens with the Palus Mareotis on the opposite side of the Moon. When, therefore, that interval between the Palus Mæotis and the periphery is at its greatest extent, then within a space of scarcely twenty-four hours the Moon wanes only so far that the line of section of light and shadow can be advanced to the innermost circle. Furthermore, it is evident from the twenty-second phase that this boundary is not only very jagged and rough, but that various brighter small areas are also seen outside it: from which it necessarily follows that mountains

and valleys stand there as well. This line of section is at times brought into the periphery itself — namely when the interval of the Mæotis appears at its narrowest, as is plain from the full Moons already mentioned, and is in fact entirely true. At that time the periphery is shown as not in the least uneven and winding, but very smooth and very even; and yet, all the same, it is known from the former case that this same periphery was jagged. It is therefore concluded that mountains and valleys stand out on the periphery itself as well.

[Margin: By sure reasons the author again concludes that mountains stand out at the very boundary, the outermost edge of the Moon.]

This can likewise be proved beyond doubt from the first and the last phase. In it that limit of light and shadow is very winding and uneven, and moreover various points, very brightly lit, are visible outside it; notwithstanding this, at a definite time this line of section, carried over into the periphery itself, is seen to be very smooth — namely when the Moon stands in Capricorn.

What has been said will perhaps seem hard to understand, above all to someone who is little versed in selenographic matters and to whom that motion of libration is still unknown. But let whoever wishes to grasp these things make himself familiar with this motion, which will be treated more fully in the eighth chapter; then I have no doubt that he will see at once that this argument of ours, which we have just brought forward to demonstrate that mountains and valleys exist on the visible periphery of the Moon, is very firm. I say nothing

of the fact that this can likewise be demonstrated from those very bright little globes attached to the horns of the horn-shaped phases, and also from the lower or upper part of the lines of section of almost all the phases, where very many peaks of mountains of the hidden hemisphere frequently show themselves.

[Margin: Why lunar mountains do not appear as clearly at the limb itself as about other boundaries.]

Further, as to the fact that the swellings and hollows at the very outermost circuit of the Moon are not as distinctly and openly visible as when the line of section stands a little away from the limb, this comes about as follows. The lunar body is sprinkled on every side with fairly high mountains, so that it appears even rougher than our Earth, as the Selenographic Map [Tabula Selenographica] attests. From this it is easily gathered that, through these innumerable mountains and the chain of crags, not only are the plains, valleys and hollows [Lacunae] covered, but the mountains themselves also seem to be linked as if in one continuous chain, as though it were some plain stretching out a very long way; for from the side we are granted only

a view of the Moon's mountains, because of the body's globular shape. We see the same thing happen on the Earth: if some spectator stands far off, placed at an equal height, then the ridges of many mountains, lying close together, appear arranged along a flat surface. "So the lofty crests of the waves of a stormy sea," says Galileo in the *Sidereus Nuncius*, p. 21, "are seen spread out along the same plane, although among the billows there are very many gulfs and troughs, and these so deep that not only the hulls of tall ships but even their sterns, masts and sails are hidden among them."

You may, however, object against this that all the same even some very small points, brightly lit, come into our view on careful inspection. This I grant, without any contradiction, to be entirely true. Did we not also show above that the periphery of the Moon, even at the very moment of full Moon, was in some measure sprinkled with swellings and hollows; and, what is more, that bright small areas — the peaks, that is, of upstanding mountains — stood out, flashing beyond the horizon [finitor] of the hemisphere? Surely these mountains must surpass all the others in height, since they shine out beyond the rest at so very great a distance.

Let this much, then, have been said briefly, as far as could be done, about the darker, varying spots of the Moon: namely, that they are nothing other than mountains and valleys standing out on the surface of the Moon, which, as I firmly believe, will also remain there until this Earth of ours, together with the whole machine of the world, is to be dissolved into nothing. It remains for us also to say what those larger spots really are which have been known on the Moon up to now and are always visible to the naked eye, over which our forebears started such great disputes; and with which earthly things, of all of them, they are most fittingly compared.

[Margin: From which it could be learned that the larger lunar spots known up to now are places levelled on every side.]

Just as, with the help of the dioptric instrument, we have learned infallibly that those parts of the Moon are swollen and pitted which, by reason of their colour and shadow — arising from the motion, altitude and distance of the Sun — are highly changeable from day to day; so in a similar way we have been able without difficulty to gather that those other parts, namely the larger, older spots, are places levelled most evenly, and for the following reasons.

[Margin: First reason.]

First: because these great spots already mentioned do not change their colour, much less their

shadow, which they cast from themselves, varying by the hour or at a certain time vanishing altogether, as was evident in those more prominent and rough parts.

[Margin: Second reason.]

Second: because the lines of section of light and shadow of all the phases, where they pass across those larger spots, are seen at every time to be very even and very smooth. For the contrary shows itself when the line of section stretches through swellings and hollows, and no observations ever contradict this; above all, such an appearance is clearly seen in phases 6, 8, 14, 15 and 28. From these it necessarily follows that those spots, which present a kind of face, are plains and places levelled altogether on every side.

[Margin: Roughness of the boundary or horizon proves that place to be mountainous; evenness of the line of section, on the other hand, indicates a plain.]

That this is the strongest test for recognising roughness and smoothness is gathered from earthly things as well — above all if, from some fairly elevated place, you look at the visible horizon and consider it well. For you will then soon notice that the horizon appears as an even stretch where it bounds some plain; but if the horizon skirts land sprinkled on every side with mountains and valleys, you will at once see the horizon [finitor] very rough, winding and uneven, just as appears in the lines of section of the lunar phases. It is therefore rightly concluded that if the boundary of the Moon is rough, that part is mountainous; but if it is flat and even, then an even surface is also found there, and this produces for us those larger spots.

[Margin: The roughness of the Moon is compared to the Earth.]

It is further asked, however, what in the end this roughness or flatness of the Moon really is — that is, of what matter it consists, and to what matter it can most rightly be compared. I answer: the swollen and uneven part of the Moon, which is otherwise the brighter, can be matched with no other earthly things known to us more fittingly than with land itself and the continent; for it takes on almost all earthly qualities. There is no reason, however, for anyone to suppose on that account that the Moon is composed of the same kind of sand, mud and stone as this Earth of ours; for it may perhaps consist of an entirely different matter, wholly unlike anything we imagine and as yet incomprehensible.

[Margin: The Moon is perhaps of a matter entirely different from the Earth's.]

This one thing I boldly affirm: these protruding, rough and brighter parts can be compared to nothing better here on Earth than to a continent; and for that reason we shall from now on call this part "land" [terra].

As for the lower-lying flat places of the Moon: those large spots, which always present themselves to us darker than the mountainous places, are no less fittingly likened to our oceans, seas, lakes, pools and marshes (which also have their windings, bays and promontories), since they appear just as constant in colour and entirely free of all shadow. Yet here again I do not mean that such lunar places are, beyond all contradiction, waters like ours; only that, because of the great affinity of the two, we have nothing at all here on Earth more similar with which we could compare those lunar ones. For I am also thoroughly convinced that the Creator of Heaven and Earth, through his divine omnipotence and infinite wisdom, could have created each heavenly body (and there are certainly many thousands of them) from the most diverse matter, in no way alike, although all are opaque bodies.

[Margin: The darker, flat parts of the Moon are compared to our seas and lakes.]

And yet there is something else besides with which these great, even spots can be compared no less suitably: for example, with certain very vast flat forests and marshes of ours. For if these were viewed from the Moon, they would likewise appear much darker than the continent and the dry land; and in the same way all sections of light and darkness passing across those spots would look very flat and very even. Since such places consist of a looser surface, they do not reflect the rays so readily: the branches and leaves of the trees hinder reflection and scatter a great many rays this way and that. But enough of this.

[Margin: Those larger spots can also be compared with our forests situated on level ground.]

You may ask, however: since those great spots already mentioned are supposed to be seas, waters, marshes and so on, why do the sections of light and shadow that cut across them not always appear in an even course too, but sometimes brighter little areas of various size are seen, both on the very boundary of the light and outside it? And for what reason are those lines of the sections sometimes seen somewhat winding? And why, sometimes, do fairly large places, scattered here and there in those great oceans, reveal themselves clearly lit, and at a fixed time shadowy as well — as experience, namely,

[Margin: Why the sections of the seas sometimes appear winding.]

bears witness? I answer: in this respect those lunar oceans differ not at all from our earthly ones. In them, just as in ours, there appear innumerable very lofty crags, and no less islands of various sizes, some flat, some also surrounded all round by steep mountains. For when these flash out in the section itself, we notice them clearly — above all those great islands that swell with mountains and are girdled by them on every side, which are then seen full of shadows

and very dark, like the other valleys that exist on the Moon. So it very often happens that the summits and ridges of mountains, brightly lit, are seen in that dark part, standing fairly far outside the section in proportion to their height. We may see something of the kind when sailing. As long as we see nothing but sea, the horizon (that is, the boundary of the light on the Moon) is seen to be even; but as soon as some island reveals itself, the loftier mountains or the taller towers are noticed at once, and afterwards the remaining lower-lying places. And while only the summits of mountains and the traces of towers are still visible, they give the same appearance as our little lit areas flashing out in that dark part.

[Margin: In the lunar oceans, no differently than in the earthly ones, there stand islands and crags.]

[Margin: Towers and the summits of mountains are the first to reveal themselves to those at sea.]

Finally, we must by all means also mention why those great spots, which present the appearance of waters, offer themselves to sight not as bright and luminous as the remaining part of the Moon — namely the continent, the mountainous and pitted places, the islands, crags, rocks and so on — although, first, water is by nature brighter and whiter, and second, it also partakes less of the black colour, as Aristotle says. Kepler too held this opinion, as is clear from his *Astronomiae Pars Optica*, p. 251. This question, however, can for the most part be explained by the reasons already given above concerning the reflection of mirrors and the rough surface of the Moon. Mirrors, namely, consist of a wholly smoothed and highly polished surface, and it is certain that for that reason the reflection of light from them is necessarily weaker than that thrown back from a rough wall or from mountainous ground. We are not speaking here, however, of the particular reflection that is presented to a particular spectator under a particular angle of inclination, but of universal light, as we noted in what has already been said.

[Margin: Reflection of light from the sea is weaker than from land.]

[Margin: The smoother the surface, the weaker the reflection.]

It is no different, then, with those seas and waters. For since their surface too is wholly smooth and even, and in this respect not unlike a polished mirror, the reflected rays are for that reason carried only to a certain determinate place. If we occupied that place, the reflection would seem very vehement and strong; in every other place, however, it would be much weaker than the reflection scattered by the land. But to understand the matter thoroughly, you must consider that the surface of the water on the Moon (properly speaking) represents a convex mirror, for the Moon is globular. Those very few reflected rays that reach the Earth under a certain angle of inclination therefore vanish altogether, both because the rays are fewer and because of the immense distance, as was shown abundantly enough in the earlier parts. So to us inhabitants of the Earth no sight is granted of the primary light that is scattered from the lunar

waters, but only of the secondary light; and for that reason the water must appear much darker than the land.

[Margin: The surface of the lunar water represents, as it were, a convex mirror.]

That things are no different here, anyone walking in the streets will notice, especially when rains have filled small hollows and pits here and there with water. When these are lit by the Sun under a certain angle of incidence, and those rays are at the same time presented to us under the same angle of reflection, it soon becomes evident that in that determinate place the reflection of the rays is very powerful, that it then presents us at the same time with an image of the Sun, and that it is stronger than the reflection of the dry ground, whose surface is so rough and opaque. But as soon as we view it from some other place, this appearance will change entirely: the dry part, standing a little higher in the streets, will scatter from itself a stronger, livelier and more pleasing light, everywhere like itself, than those watery places, which will be much darker. Moreover, that light will be more universal and more constant from whatever place you look at it, because a rough and uneven surface can reflect rays in every direction by means of innumerable angles of inclination, which an even surface — that of water, namely — by no means can.

[Margin: That the reflection of water is weaker than that of land is proved by experiment.]

[Margin: A rugged surface reflects rays in every direction.]

I conclude, therefore, that the brightly lit surface of the Moon is land, and the larger, darker spots are waters, just as

[Margin: It is affirmed that the brighter part of the Moon is land, and the darker part water.]

Kepler too, most renowned in the science of the stars, concedes in his dissertation with the *Sidereal Messenger* [*Dissertatio cum Nuncio Sidereo*], page 29, saying: "I grant that the spots are seas; I grant that the bright parts are land." He grants, further, that the Moon is not unlike our Earth, since there, no differently than here on Earth, great oceans, seas, pools, lakes, marshes and so on exist, with winding bays and innumerable promontories; and moreover that continents, peninsulas and islands are also seen on the Moon, partly flat, with very vast plains in them, and partly filled with steep cliffs and very lofty mountains, whose ranges stretch out as far as they can reach. These will be treated at length later.

CAPUT VII.

Chapter VII.

On the motion of the Moon, its parallaxes, refractions, distance, magnitude and apparent diameter. So that all these may be explained the more clearly, the whole body of the world — its figure, quantity and motion — and also the various hypotheses of

the astronomers are discussed at the same time, briefly, yet clearly, as the plan of the work requires.

In the single little word *World*, namely, there is comprehended briefly and in sum not only the whole terrestrial globe, whatever exists on its surface and in its interior, but also the starry heaven spread wide on every side, as well as all the ethereal bodies, those known so far as much as those unknown, and indeed whatever God has ever founded and created in it. And yet it is truly a difficult matter to philosophize correctly about all the things of the world, even if only the doctrines of the philosophers, ancient as much as modern, are to be brought forward — let alone if anything certain and indubitable is to be established about them. You will gather this also from the infinite variety of innumerable writers, where nevertheless scarcely the smallest part of the things has been explained, which

are contained in the exceedingly ample volume of Nature. And although a great many literary works may yet be published, right up to the last day, the weightier and principal matters will nevertheless be left wholly untouched. There is no reason, therefore, for anyone to persuade himself that I intend to treat the universe fully and completely in this very slight little commentary: I shall touch only on those things that necessarily concern its figure in general, its magnitude and its motion.

[Margin: Whether the World is finite or infinite.]

At the outset a difficult and wide-ranging question presents itself: namely, whether the World is finite or infinite. Certain of the ancient philosophers — Anaximander, Solenus, Melissus, Leucippus, in part also Diogenes of Apollonia, and most of the Stoics — maintained the latter, as did, among the moderns, Iordanus Brunus [Giordano Bruno], Francesco Patrizi and others. There is likewise another question: whether the World is finite in a finite or in an infinite space, as may be seen in Kepler's *Epitome Astronomiae Copernicanae*, book 1, and in Patrizi's *Pancosmia*. Since both questions, however, are purely philosophical, I gladly leave them for others to debate, lest I seem to dwell too long on matters of this kind, beyond our purpose and aim. For I am, besides, wholly of the opinion that no one has yet settled the matter completely or established anything certain about it — not to say gone so far as to demonstrate, by indubitable and invincible reasons, that the World has a figure, and indeed is bounded by a spherical figure — however much Aristotle left no stone unturned on this point.

[Margin: Whether the World is finite in a finite or an infinite space.]

Meanwhile, however (even though much could be brought forward on the contrary side), what nearly all the most eminent philosophers approve is granted without reluctance: that the World is entirely round, like the Earth, the Sun, the Moon, and indeed almost all the heavenly bodies. For it is credible that what contains all things is also wholly of the same figure as the things comprehended in it, and indeed of the kind that is the most capacious of all,

as the circle is; for to the most perfect body, they say, the most perfect figure must also be assigned, namely the circle.

[Margin: That the World is bounded by a spherical figure.]

But whether the heaven is corruptible or incorruptible, simple or compound, or rather some fifth essence, much

[Margin: Whether the heaven is corruptible or incorruptible.]

is disputed. But since mention has been made of this matter here and there in the preceding parts, I shall not press these points at greater length now.

[Margin: From which element the firmament consists.]

Here, however, another question is put: namely, whether the firmament, or starry heaven, or the stars themselves as well, consist of air, water or fire. Aristotle, with all his followers, asserts that the heaven is a fifth essence, of which the stars are the denser parts, as I have already mentioned above.

[Margin: Plato's view on this matter.]

Plato, however, taught in the *Timaeus* that the heaven consists of all four elements, yet of their purer parts, and that it partakes more of earth and fire; Alcinous also reports this in chapter 12 of *On the Doctrine of Plato*.

[Margin: The view of the Platonists.]

The nobler part of the Platonists — namely Iamblichus, Syrianus and Proclus — say that the purest summits of the elemental qualities are present in the heaven, but that the heaven is fiery by predominance; Plotinus says that it is nothing other than fire.

[Margin: That the heaven is fiery.]

So too many among the Greek philosophers held that the heaven is fiery: namely Thales, Anaximenes, Heraclius, Xenophanes, Parmenides, Empedocles, Anaxagoras, Diogenes, Archelaus and Cleanthes. Among the theologians, Damascenus [John of Damascus], Augustine, Cyril and others stand on the side of the Platonists. Whoever wants more on this matter, and to learn that the heaven is wholly of the same nature as the elements (and I myself think no differently), should read chapter 38 of book 11 of Vossius's *De idololatria*.

[Margin: That the World is animate.]

Besides these philosophers and theologians already named, moreover, Zoroaster, Hermes, Orpheus, Zeno, Pythagoras and almost all the Egyptians and Chaldeans assigned a soul not only to the stars but also to the whole World, and held it to be animate. (Of these Francesco Patrizi, in book 12, page 91, speaks thus on the number of the heavens: "Because they are living beings, and indeed divine ones, they must of necessity have a divine mind, a divine life and a divine intellect.") They plainly believed that the World is an eternal living being, embracing within itself all the genera and species of living beings, and moreover blessed, all-seeing, all-hearing, and endowed with a rational soul and a divine mind; as appears especially from book 32, *de natura*, Platon., page 709: "That the World is a living being, and an intelligent one, truly constituted by divine providence." Further, page 713: "Because they are divine living beings, they therefore always persevere in the same circuit." This, indeed, by some

[Margin: That the World is a living being endowed with a divine mind.]

[Margin: That the stars are endowed with a sensitive soul.]

Peripatetics is affirmed — namely Alexander [of Aphrodisias], Philoponus and Simplicius, who say: "Not only are the stars animate, but they are also endowed with a sensitive soul" — on the testimony of the same Patrizi. Very many of the Fathers, too — namely Lactantius, Basil, Ambrose and Cyril — said that the World is animate.

[Margin: What the soul of the World is.]

This soul of the World (which is, besides, nothing other than a certain life-giving power, divinely infused into the whole World and into all its parts, by which all things live in their own state, are sustained, and put forth their powers) the most learned Comenius [Jan Amos Komenský] calls the *Spirit of the World*; "which", he says, "is nothing other than the very life infused into the World for working all things in all things" (page 25, in the *Synopsis Physicae*). The contrary was held among the philosophers by Leucippus, Democritus and Epicurus.

[Margin: Aristotle removes the qualities of the elements from the heaven.]

Aristotle, however, takes a middle way, in that he holds that a part of the World, not the whole, is animate; but he took away from the heaven all the qualities and essences of the elements. Some of the Fathers did the same, such as Origen, Jerome and Augustine, and among more recent writers Aureolus [Pierre Auriol], Scotus [John Duns Scotus], St Thomas Aquinas, Cajetanus [Cajetan, Tommaso de Vio], and others.

[Margin: Whether the heaven is movable or immovable.]

Further, whether the heaven is movable or immovable is worth considering. I can easily gather, however, that many will think this question wholly superfluous, and that it is most absurd to raise a doubt about the immobility of the heaven, since every year — indeed every day — we can know this beyond doubt and plainly from the rising and setting of the stars, the Sun and the Moon. But truly, kind Reader, we must here distinguish carefully between the motion of the stars and the other celestial bodies, and the motion of the heaven itself, as the dwelling-place of those bodies.

[Margin: How the stars are moved.]

For there is no one who doubts that the stars move, nor is that in dispute at present. Indeed, we are of the opinion — as will also be demonstrated more fully hereafter — that the celestial bodies move in the ethereal air like birds in the air or fish in water, or rather like some ball fired from a cannon.

[Margin: Aristotle feigns real spheres in the heaven.]

If, however, the heaven is to move, it is necessary to suppose, with the Aristotelians, the Ptolemaics and the Alphonsines, real spheres in the heaven: that is, that each planet is carried round by its own particular sphere, to which it firmly adheres, as appears in those armillary spheres. But that these things are impossible, and moreover mere fictions, will very soon be plain, as soon as

it is demonstrated that the heaven is liquid and fluid. From this it will necessarily follow that those ethereal bodies, because of that fluidity and thinness of the heaven, cannot adhere to particular spheres : just as in water, air, fire or any other liquid and fluid matter of this kind, nothing whatever is held fast. It will therefore be clearly established that the heaven, as the lodging of the stars, does not in reality move of itself; but that only the stars and the celestial bodies are carried freely, without any hindrance, in that purest ethereal air with which the whole dwelling-place of the stars is filled.

[Margin: What the ethereal air is.]

This air is almost nothing other than the purest air, as very many hold. Patrizi, however, says in book 7, page 17: "The substance of the aether is nothing other than pure light."

But, to return to my purpose and at the same time to show clearly the fluidity, liquidity and thinness of the heaven, and that no hardness or solidity of the air, like that of adamant, can exist in the heaven, nor diverse real spheres, nor distinct heavens — a view to which very many of the moderns have been devoted, not to mention the ancients; among them not the lowest place is held by Copernicus, Tycho Brahe, Rothmannus [Christoph Rothmann], Kepler, Möestlinus [Michael Mästlin], Galileo, Longomontanus, Origanus, Gassendi, Bullialdus [Ismaël Boulliau], Blancanus [Giuseppe Biancani], Sempilius [Hugh Sempill], Ciccus Esculanus [Cecco d'Ascoli], Michael Scotus [Michael Scot], Stevinus [Simon Stevin], Snellius [Willebrord Snel], Clavius [Christoph Clavius], Maginus [Giovanni Antonio Magini], Scheiner, Crüger, Eichstaedt, Linemann — indeed almost all the mathematicians of our own time.

Firstly, this view is corroborated by the following reasons. If the heaven were a body of its own kind, and had an essence wholly different from our air, and moreover consisted of as many diverse real, solid and impervious spheres, contiguous with one another, as there are wandering globes of stars counted, then certainly no fixed star or other celestial body would ever be observed in its true and proper place, and still less would any conjunction or eclipse answer to calculation, by reason of the various refractions occurring at the diverse surfaces of the spheres — as optics, namely, attests most clearly.

[Margin: Refraction removes the celestial bodies from their true place.]

If, therefore, anything of the kind happened in the heaven, it would be all over with the whole of astronomy; indeed, all the observations of the most distinguished men — of Hipparchus, Ptolemy, Copernicus and Tycho — would collapse entirely. But since absolutely no refraction, in all ob-

servations over so many centuries, has been detected, it is concluded quite evidently from optics that the ethereal space between the Moon and the fixed stars differs in nothing whatever from our sublunary air — just as Mersenne, likewise, set out to confirm the same thing most lucidly in his commentary on Genesis [Comment. in Genef.], chapter 1, page 812.

Secondly, since the surface of the Moon is plainly rough and uneven, crowded on every side with very high mountains — as has already become

known in part, and will hereafter become plain to many more — it must likewise be concluded from this that the heaven is by no means hard, solid and impervious; otherwise it could not move unless a vacuum were granted, or a penetration of bodies, as anyone will easily be able to gather.

[Margin: If the heaven were hard, a penetration of bodies would necessarily follow.]

Thirdly, that all the planets acknowledge the Sun as their centre needs no further arguments now. Hence Mars, Venus and Mercury are at one time raised above the Sun and at another seen below it, as the phases of Venus and Mercury attest. If, then, the heaven is granted to be hard and impervious, good God, what a penetration of bodies and of dimensions would arise from it when these planets already mentioned intersected the sphere of the Sun! Something similar would happen with the Jovials and the circumsaturnals, unless you posit the heaven to be liquid and fluid.

[Margin: Granted the fluidity of the heaven, all phenomena are more easily understood and saved.]

Fourthly, I would truly be glad to learn from some Peripatetic how new stars (of which nine or ten of outstanding magnitude have appeared in the heaven, and among the fixed stars themselves) or comets (some of which have been higher than the Sun itself) are generated and corrupted, or how they move and are carried aloft, if real spheres were granted — to say nothing of the faculae and the solar spots, which likewise arise around the Sun, move, and are reduced to nothing. So it is most certain that no phenomenon appears which cannot be conceived, saved and explained far more easily, granted the thinness or liquidity of the heaven, than if we suppose the celestial orbs to be hard and adamantine.

[Margin: There is one heaven, and it is liquid.]

I conclude, therefore, with almost all the most distinguished astronomers and philosophers, that there is one single heaven, and that ethereal, liquid like the air, in which the stars and planets move; and that it is not the heaven itself, or stars fixed in orbs, that are carried round. This opinion, on the testimony of

Patrizi, book 17, page 104, brought every evil into astronomy and physics. Anyone who wants to learn more on this — namely on the liquid heaven — gathered from countless authors, philosophers and Fathers, should read part II, book 4 of the *Rosa Ursina*, chapters 26, 27 and following.

[Margin: The invention of astronomical hypotheses is most useful and most ingenious.]

Since, then, two different opinions are now held among the learned, ancient and modern alike — some of whom imagine real spheres in the heaven, while others suppose the heaven to be liquid — different hypotheses are accordingly laid down by them as well. In astronomy these do as much as axioms do in geometry, and they are rightly called the true sensible principles of the sidereal science, since through these hypotheses the figure, order and motion of the celestial bodies are placed before our eyes. I certainly cannot help marvelling, first, that the human mind was able to devise and discover such hypotheses —

that is, if such an order and constitution of bodies is indeed present there in the heaven. Secondly, even if the constitution, figure, order and motion of the starry heaven should be quite other than, and different from, our opinion, one must nonetheless marvel that these hypotheses, devised by men and as it were feigned, have so very close an affinity with the heaven and the stars themselves that with their help the celestial motions can be predicted and computed with the greatest certainty, even several centuries into the future. From this it is plainly evident that these hypotheses are not the ravings of astronomers, as a certain philosopher thinks, whose name I do not wish to disclose, out of respect for him.

[Margin: On the first invention of the hypotheses.]

Of these hypotheses there are three principal forms, to pass over the various others: namely, 1. the Peripatetic or Ptolemaic, 2. the Tychonic, 3. the Pythagorean or Copernican. To deal briefly at the outset with the origin of the first hypothesis, and with the reasons that moved its authors to lay down such a thing, it should be known that, after the ancient Chaldaeans and Egyptians, the first investigators of the stars, had clearly seen and observed not only that every day, in the space of twenty-four hours, all the stars and ethereal bodies are moved and carried round from their rising, through the meridian, to their setting, but also that, besides this motion, the Sun, the Moon and likewise the other planets, by a further motion of their own, from

the setting towards the rising, were endowed with motion — even though the motion of one planet was far swifter than that of another — they accordingly laid down as many real spheres as the different motions they had noticed in the heaven, namely eight. So they took the outermost for the firmament and called its stars fixed, since at first they detected no other motion about them than that diurnal one from rising to setting; and finally they placed the Earth in the middle, as the centre, and immovable at that.

[Margin: On the order of the spheres the ancients do not agree among themselves.]

As for the order of the planets, or of the spheres by which they are to be moved, the ancients do not all keep one and the same order, although they agree among themselves on this much: that the next greatest sphere, nearer to the fixed stars, is Saturn's; that those of Jupiter and Mars are next to it; and that after them, as most of the Chaldaeans hold, with Cicero's assent, comes the sphere of the Sun. The Egyptians, however, together with Plato and Aristotle — as one reads in Plutarch, book 2, chapter 15, *On the Opinions of the Philosophers* [de Placitis Philof.], and in the divine Plato, book 32, *On Nature*, page 713 — placed Mercury immediately after Mars, then Venus, the Sun, and finally the Moon, nearest to the Earth. The highest sphere, that of the fixed stars — the eighth, namely, the firmament — they held to be the primum mobile, which carries the spheres of the other planets round with it, all together, in twenty-four hours, from rising to setting, against the order of the signs; and this motion is otherwise called the diurnal motion of the stars.

[Margin: The real spheres of the ancients were divided into more.]

These eight spheres already mentioned (which the Aristotelians and Peripatetics held to be truly real, with all the stars fixed in them like a nail in a wall, and revolving round together with them) Eudoxus and Callippus in turn divided into 53 or 54, as can be seen at length in Aristotle, book 12, chapter 8 of the *Metaphysics*, and also in Kepler, chapter 2, page 6, *On the Motions of Mars* [de Motibus Martis].

After Ptolemy, the prince of the ancient astronomers, had clearly perceived from the observations of Timocharis and Hipparchus that the eighth sphere, in addition,

had a peculiar motion of its own, from setting towards rising, although a very slow one, he therefore judged it necessary to add a ninth to the previous 8, so that this last might stand in place of the primum mobile and accomplish that diurnal motion.

The Alphonsine astronomers, however, who lived 1110 years after Ptolemy and had been convened by King Alfonso of Castile, concluded on sure grounds that the number of spheres had to be increased still further, because they had found that the fixed stars had varied their declinations since Ptolemy's time. This motion they called the motion of trepidation and assigned to the eighth sphere, so that a tenth was added to represent the primum mobile. To these ten spheres later writers added an eleventh, namely the Empyrean Heaven, the seat of GOD, of the angels and of the blessed.

[Margin: The Alphonsines placed the Earth immovable at the centre.]

[Margin: The order of the spheres in the Ptolemaic hypothesis.]

In this Ptolemaic-Alphonsine hypothesis, then, the earlier astronomers had our Earth, immovable, as the centre; around it the four elements; then the Moon and its sphere, since its motion is the swiftest of all the celestial bodies, completing its course by its own motion in about four weeks. 2. Next they assigned the second sphere to Mercury, which is the most rapid after the Moon. 3. To Venus, because it was a little slower, the third sphere was accordingly attributed. 4. This is followed by the Sun, which runs through the twelve celestial signs in the space of one year. 5. Then Mars, since it completes its course in only two years. 6. Next Jupiter, which traverses its circle in no more than twelve years. 7. After Jupiter follows the sphere of Saturn, for Saturn is the slowest of all the planets, travelling round its circle in about thirty years. Saturn is succeeded by the eighth sphere, namely that of the fixed stars, whose revolutions in small circles set at the heads of Aries and Libra are restored in 7000 years, in which time the anomalies of the equinoxes return to the same point. After this they laid down a ninth, which its own proper motion, in the order of the signs, in 49,000

years first completes. Finally, the Tenth surrounds all the rest. It performs the diurnal revolutions, and moves and sweeps along with it all the spheres together, those of the fixed stars as well as those of the wandering stars, against the order of the signs, from rising to setting. From this it follows that the

heaven is moved with a threefold motion: 1. the diurnal motion; 2. the proper motion; 3. the motion of trepidation, which is carried towards the pole of the world. This order of the spheres of the celestial bodies is clearly delineated in the following figure.

[Margin: The heaven is moved with a threefold motion.]

Diagram. *The Ptolemaic-Alphonsine Hypothesis.* An engraved diagram of concentric circles round a shaded Earth at the centre. Moving outwards, the bands are labelled as the spheres of the elements and of the planets, then the starry band of the fixed stars, then the ninth, tenth and eleventh spheres. Below the Earth, a vertical column of planet symbols stands in the successive bands. The signs of the zodiac are set round the ring outside the tenth sphere. Engraver's mark at lower right.

- Centre, split either side of the Earth: "Ele menta" — the elements
- Rings above the Earth, from the inside outwards: "Aer." — Air; "Ignis." — Fire; "Lunæ." — of the Moon; "Mercurii." — of Mercury; "Veneris." — of Venus; "Solis." — of the Sun; "Martis." — of Mars; "Iovis." — of Jupiter; "Saturni." — of Saturn
- Starry band, top: "Sphæra VIII." — Sphere VIII; bottom: "Fixarum." — of the fixed stars
- Next ring, top: "Sphæra IX."; bottom: "Trepidationis." — of trepidation
- Next ring, top: "Sphæra ♋ X."; bottom: "Primum ♈ Mobile." — the primum mobile (♋ and ♈ stand on the vertical diameter)
- Outermost ring, top: "Sphæra XI."; bottom: "Coelum Empyreum." — the Empyrean Heaven
- Below the Earth, from the inside outwards: ☾ ☿ ♀ ☉ ♂ ♃ ♄
- Zodiac signs round the ring, anticlockwise from the right: ♈, ♉ [?], ♊, ♋ (top), ♌, ♍, ♎ (left), ♏, ♐, ♑ (bottom), ♒, ♓
- Lower right: "Ant. Sc." — engraver's signature

It would indeed now be fitting to say something about the Pythagorean and Copernican system. For certain reasons, however, even though that system is the older, I shall first bring forward something about the Tychonic system, and speak of the Pythagorean afterwards.

[Margin: On the Tychonic System.]

That great Danish Atlas, Tycho Brahe, had seen clearly enough from his very careful observations, made over a span of twenty-five years with the help of his far from ordinary instruments, that many celestial phenomena still remained which could not yet be saved and explained by the Ptolemaic and Alphonsine hypothesis. Among others there was the phenomenon of Mars at acronychal rising [Martis Acronychi]: at the time of its opposition to the Sun it becomes much nearer to the Earth than to the Sun itself, and at conjunction, in turn, it is much farther from the Earth than the Sun is. (In the earlier hypothesis the real spheres invented by the Peripatetics prevent this from being possible.) He therefore devised an entirely different system. As its stable foundation he first laid down, in place of a solid and hard heaven, a fluid and continuous one,

in which the stars, by a certain natural force, move freely and without any impediment, as they have from the beginning of the world until now, by fixed laws, yet within fixed limits.

2. He kept the Earth immovable at the centre of the world, but in such a way that it is the centre only of the path of the Moon, of the Sun and of the fixed stars.
3. He made the Sun the centre of all the remaining planets, as Copernicus did, of whom more later. It differs, however, in this: in Tycho the Sun, in its own circle or ecliptic, necessarily carries round with it that very ample planetary system, whereas in Copernicus the Earth, placed in the ecliptic, carries round with it only that very small lunar sphere.
4. The circle nearest the Sun is that of Mercury, the next that of Venus, like two epicycles. Then Mars follows at a very great interval. Its heaven, at opposition, cuts away a large part of the solar heaven, so that when Mars is acronychal it becomes nearer to the Earth than to the Sun. Next follows the heaven of Jupiter, then of Saturn, and finally the sphere that comprises all the others within itself, namely the sphere of the fixed stars. This, together with the rest, is revolved by the diurnal motion from rising to setting:

as this order of the celestial bodies is clearly shown by the accompanying diagram.

Diagram. *The Tychonic Hypothesis.* An engraved diagram with the Earth at the centre inside the Moon's circle, which is enclosed by the circle of the Sun. Above the Earth, overlapping the Sun's circle, stand two small nested circles labelled for Venus and Mercury, and round these three large circles labelled for Mars, Jupiter and Saturn. A starry band, the sphere of the fixed stars, encloses all. A legend stands in the lower half. Engraver's mark at lower right.

- Top of the starry band: "Sphæra Fixarum." — sphere of the fixed stars
- Top, on the large circles, from the outside inwards: ♄, ♃, ♂
- Left of the three large circles: "Circulus." (three times); right: "Saturni.", "Iovis.", "Martis." — circle of Saturn, of Jupiter, of Mars
- Sun's circle: "Circulus." (left), "Solis." (right) — circle of the Sun
- Small circles about the Sun: "Circ." "Veneri." — circle of Venus; "Circ." "Merc." — circle of Mercury; with the symbols ♀ and ☿ at their tops
- Circle about the Earth: "Circul." "Lunæ" — circle of the Moon; at the centre, "Ele menta" — the elements
- Legend: "Solem huc deſcendentem concomitatur totum Syſtema Planetarium" — "The whole planetary system accompanies the Sun as it descends here"
- Lower right: "Ant. Sc." — engraver's signature

[Margin: On the Pythagorean hypothesis.]

Now, as regards the Pythagorean hypothesis: almost all the Pythagoreans were devoted to it, above all Philolaus of Croton, Aristarchus of Samos, Plato in his old age, and very many others, as Plutarch testifies in book 3, chapter

13 of *On the Opinions of the Philosophers*, and Archimedes in his *Sand-Reckoner* [Arenarius], page 449. Afterwards, however, this hypothesis lay in deep silence for several centuries, until about a hundred and thirty years ago Copernicus, our fellow citizen, a man never praised enough, born by the singular providence of GOD, came forward. He raised that ancient and almost forgotten hypothesis again from its ashes, and not only made it clearer but also, in various places where it was needed, more perfect.

[Margin: Copernicus, restorer of the Pythagorean hypothesis.]

Almost all the eminent mathematicians of this age of ours embrace this opinion, and labour more and more to defend it against the objections of those who contradict it; since by this

very happily and conveniently, all the phenomena and motions of the stars, in longitude as well as in latitude, are explained and understood, as are the retrogressions of the planets (that is, why at certain times they are slower, faster, stationary [?], and so on), so that this view seems less at odds with reason.

[Margin: By this hypothesis all the phenomena of the stars are explained most easily.]

Whoever wants more on this system and opinion, and in more detail, demonstrated from indubitable geometrical foundations, should read, among other astronomers of our age: *Philolaus Redivivus*, written by a man of the highest genius; the *System of the World* of Galileo Galilei, truly a Lynx among the Italians; the second letter of Pierre Gassendi, a man of immense learning, *On Motion Impressed by a Moving Body in Translation* [de motu impreſſo à Motore tranſlato]; the *Epitome Astronomiae Copernicanae* of Kepler, the eagle of the German mathematicians; Philips van Lansbergen; and others. For it is not my purpose to establish this hypothesis fully, nor is this the place for it. Nevertheless I shall go on to touch briefly on the order and motion of the stars, as far as the plan I have set myself requires, so that I may the more easily explain and demonstrate the Moon's particular motion — a motion of which no one ought to be ignorant, if this *Selenographia*, and whatever will be said hereafter about the lunar phases, the motion of the Moon's libration, and various phenomena, are to be rightly understood.

[Margin: Without knowledge of the Moon's motions this *Selenographia* is not understood at all.]

To begin with, those astronomers, whom I have praised and whom I am to follow here, place the Sun, as the soul of the world, at the centre of the universe. It is motionless, indeed, as regards motion of translation [motus lationis], but it nevertheless turns about its own axis in about 25, 26 or 27 days (as can be clearly deduced from the spots).

[Margin: The Sun, the centre of the universe, is moved about its own axis.]

Immediately round the Sun they set the sphere of Mercury, the smallest of all, and mobile; next that of Venus; after that the orb which Copernicus calls the great orb [orbis magnus]. In this our Earth, together with the air poured

round it and the sphere of the Moon, moves like an epicycle — and indeed with a threefold motion.

[Margin: The order of the orbs.]

First, the Earth is carried round the Sun in the great orb in the space of a year. Second, while it moves in this way, it also turns at the same time about its own axis, from west through south to east, in the order of the signs, towards the Sun each day, with a daily revolution in twenty-four hours, like a small ball on a turning-bench. Since it therefore turns towards the east in this way, all the stars and planets, indeed the Sun itself,

[Margin: The Earth is moved with a threefold motion.]

recede towards the west and set, each in its own time.

Third, the axis of the Earth (which continually keeps most exactly to that northern and southern point) librates by 24′ [quatuor viginti min.] to either side; and by this motion Copernicus demonstrates the change in the obliquity of the ecliptic.

Since, therefore, on the opinion just stated, the Earth is carried in the ecliptic in three ways, following the course of the zodiac, the Sun appears to us in Aries when the Earth is in fact in Libra; and when the Earth is in Scorpio, the Sun is seen in Taurus. So the Earth completes its annual motion by a spiral motion: that is, it turns about its axis about 365 times [trecenties fexagies quinquies] before it can complete the whole zodiac. In this space of a year the Moon by itself (leaving aside that earlier motion of the Earth) runs through its own sphere — which the Earth otherwise carries along with it — twelve times; and from this the full moons, new moons, quadratures and lunar months take their origin.

[Margin: The Earth runs through the ecliptic by a spiral motion.]

Here, I suppose, someone will readily think this a strange revolution, almost contrary to reason: that the Earth should carry the whole sphere of the Moon round with it, together with the air poured about it. But I reply that this, whatever it may be, is nevertheless more in agreement with reason than what the Tychonic hypothesis requires: that the Sun must continually sweep along with it, every year — indeed every day and every hour — the whole planetary machine, so vast a space, together with the planets, bodies of such enormous size that they exceed the Moon many times over in vastness; and further, that the primum mobile must carry the Sun, with all the planets and fixed stars, along with it by a motion, and a contrary one at that, from east to west — to say nothing of the remaining difficulties that present themselves in abundance concerning this motion of the primum mobile.

After the great orb comes the orb of Mars, then that of Jupiter, round which four small epicycles, as it were, are seen; in these the four companions of Jupiter revolve. Although they complete their periods on their own, they always accompany Jupiter's motion and revere him as their king, just as the other planets revere the Sun. In this age this can be demonstrated clearly and openly

with optical tubes, and proved by the sense of sight. From this it is indeed quite evident that it is not so absurd and incongruous that the Earth

should carry the whole lunar sphere round with it, since we see that Jupiter can turn 4 such little moons round with it (which are themselves of no small size, since some of them measure 400 German miles in circumference) without any hindrance or retardation in the ethereal air — that is, in a fluid and liquid heaven.

[Margin: Just as Jupiter carries the Jovials round with it, so the Earth carries the Moon.]

Finally comes the orb of Saturn, round which, in a similar way, two small epicycles are given, in which the two circumsaturnals move. At certain times, when they are very close to it, these form, together with the body of Saturn itself, a strange and unfamiliar figure; their motion, however, has not yet been fully investigated.

After Saturn a most vast interval is laid down, between it and the sphere of the fixed stars. This space, I believe, with the most learned Philolaus Redivivus, is scarcely empty of the bodies of stars; just as I am also not persuaded that all the fixed stars are removed from the Sun at an equal distance — although others have thoroughly persuaded themselves of this, namely that they are fixed to a single sphere, like the little stars painted on that artificial globe. Very many of the ancients, too, were attached to this opinion, as is clear from Geminus, who says: *"The highest of all, then, is the sphere called that of the fixed stars, which contains in itself the image of all the fixed constellations, or signs. But it must not be thought that all the stars are set beneath the same surface; rather, some are higher and others lower. For since our sight extends to an equal length from the Earth into the heavens, the difference in height is rendered imperceptible."* So he writes, in the *Uranologion* of Pétau, page 4.

[Margin: The interval between Saturn and the sphere of the fixed stars is by no means empty.]

[Margin: Not all the fixed stars are equally distant from the Sun.]

In this hypothesis it is laid down not only that the Earth's semidiameter, but also the whole semidiameter of the great orb, is like a point relative to the semidiameter of the sphere of the fixed stars; and that the whole distance between the Sun and the Earth (which equals about 1200 semidiameters of the Earth) is entirely imperceptible relative to the sphere of the fixed stars, so that parallel lines drawn from the Earth and from the Sun to the fixed stars almost coincide in one and the same point. For this reason, too, so vast a space is left above Saturn. The proportion of the whole planetary system to the semidiameter of the firmament is as that of a pea to fifteen Danzig feet, as the most learned Master Peter Crüger — now among the blessed and borne far above the aether, once my most highly revered teacher, mathematician of Danzig — (to whose diligence and learning in

[Margin: The whole distance of the Sun and the Earth vanishes entirely relative to the sphere of the fixed stars.]

[Margin: What is the proportion of the globe of the planetary system to the semidiameter of the firmament?]

mathematical matters I confess that words fail me to praise as they deserve) noted in his *Astronomia Dantiscana*, book 1, chapter 2 — a work which he did indeed begin, but did not bring quite to its conclusion. And Kepler says, in the *Epitome Astronom.*, book 4, page 492:

"The diameter of Saturn, the outermost sphere of the movable bodies, contains in itself the diameter of the solar body about two thousand times; likewise the diameter of the sphere of the fixed stars contains in itself the diameter of Saturn nearly two thousand times. Therefore the diameter of the fixed stars will contain in itself about four million diameters of the solar body, and the diameter of the Earth (according to the proportion of the bodies of the Sun and the Earth believed by the ancients) fivefold and more."

Here, someone will readily reflect: good GOD! how immense, how incredible and incomprehensible a distance, height and breadth is urged on us in this hypothesis? But this view may well be more probable than that of the ancients — that the sphere of the fixed stars revolves four thousand times faster than in Copernicus, and that the greatest sphere has the fastest motion while, on the contrary, the smallest, namely the Moon's, moves far more slowly. And yet at the outset the ancients themselves derived the distance and elongation of the stars, or of the spheres, from their faster and slower motion; that is to say, they concluded that a star which was faster lay lower than a slower one. From this foundation they deduced the order and position of the planets, or of those spheres, which they also observed correctly as far as Saturn. But at the sphere of the fixed stars they consigned this reasoning and this infallible rule entirely to oblivion, and in this way destroyed almost their whole hypothesis.

[Margin: It is contrary to nature that the greatest sphere should have the fastest motion.]

In the Copernican hypothesis, by contrast, everything follows in order and consistently: there, the higher a planet stands, the slower the motion attributed to it, and to the greatest sphere the slowest of all. Further, just as the Sun is set as the centre of the universe, so it is asserted of its motion that it turns about its axis in about 27 days, as was said above. Mercury's revolution is completed in $87^{d}\ 23^{h}\ 45^{m}$. Venus, which stands a little farther from the centre, completes its period in $224^{d}\ 17^{h}\ 26^{m}$. The Earth, more remote still from the Sun, runs its circle in $365^{d}\ 5^{h}\ 49^{m}$. Mars completes its period in one Egyptian year, namely, and $321^{d}\ 22^{h}\ 24^{m}$; that is, in one

[Margin: The periods of revolution of the planets.]

Julian year, 10 months, $17^{d}\ 22^{h}\ 21^{m}$. Jupiter completes its period in 11 Egyptian years, $315^{d}\ 17^{h}\ 14^{m}$; that is, in 11 Julian years, 10 months, $9^{d}\ 14^{h}\ 10^{m}$. Saturn, the most remote of all the rest, completes its course in 29 Egyptian years, $162^{d}\ 3^{h}$; that is, in 29 Julian years, 5 months, $4^{d}\ 12^{m}$. And this is all I wished to say

about the Copernican hypothesis — except that, so that the whole matter may come out clearer, I should like to set its diagram here as well.

Diagram. *The Copernican Hypothesis.* An engraved diagram of concentric circles about the Sun, which is drawn as a rayed disc at the centre. From the outside inwards: a broad ring scattered with stars, labelled at the top "Sphere of the Fixed Stars" and at the bottom "Immovable"; inside it a wide band labelled at the top "Most Ample Interval" and at the bottom "Empty of stars"; then the orbs of Saturn, Jupiter and Mars; then the great orb carrying the Earth, on which a small circle marked "Ter." (Earth) has a crescent Moon drawn above and below it on its own small circle; then the orbs of Venus and of Mercury about the Sun. Planet symbols are set on a vertical line below the Sun. The engraver's signature stands at the lower right.

- Title (top, outside the circles): "Hÿpothe[[c/ſ]]is Copernicana." — The Copernican Hypothesis
- Outer starred ring, top: "Sph[[æ/a]]ra Stellarum Fixarum." — Sphere of the Fixed Stars
- Outer starred ring, bottom: "Immobilis." — Immovable
- Band inside the stars, top: "Interſtitium Ampliſsimum" — Most Ample Interval
- Same band, bottom: "Stellis vacuum." — Empty of stars
- "Orbis Saturni." — Orb of Saturn
- "Orbis Iovis." — Orb of Jupiter
- "Orbis Martis." — Orb of Mars
- Small circle on the Earth's orb: "Ter." — Earth
- Down the left and right of the Earth's orb: "Orbis Magnus … Lunam Terramq́ue … deferens" — the great orb, carrying the Moon and the Earth
- "Orbis Veneris" — Orb of Venus
- "Orbis Mercurii" — Orb of Mercury
- Vertical line below the Sun, in order outward: ☿ ♀ ♂ ♃ ♄ (Mercury, Venus, Mars, Jupiter, Saturn)
- Lower right: "Aut. Sculps." — engraved by the author
- Labels not read: two small strokes before "Orbis" on Saturn's orb [?].

Let us now gird ourselves, according to the plan proposed, to set about explaining the particular theory and motion of the Moon. This cannot, indeed, be done fully and at length for the present (that is, if any account is to be taken of time): for the matter is spread far and wide, so that even to have written a huge volume on it would not suffice, since all mathematicians admit that the motion of the Moon is intricate beyond the motions of the other planets. Nonetheless I shall take pains to set everything out quite clearly, and as briefly as possible, for all students of astronomy.

[Margin: The motion of the Moon is the most difficult of all.]

For this reason, too, I have resolved to explain the motion of the Moon not in Kepler's manner, by an elliptical orbit, but in the Tychonic manner, by

circular orbits and epicycles. This is not, indeed, because I hold this hypothesis to be preferred, as it were, to the other, or because it pleases me more — by no means. For I am entirely of the opinion that Kepler's hypothesis is to be embraced before all the rest, since, once it is adopted — to say nothing of other reasons — not only does the motion of the planets become simpler, by a single simple elliptical line, but in addition so many superfluous circles, or epicycles, are removed altogether, and at the same time the contrary motion of the centres is avoided.

[Margin: Why the author has not explained the motion of the Moon by an elliptical orbit.]

[Margin: Kepler's hypothesis is to be preferred to all.]

Perhaps you ask, kind reader, why then I have not chosen this more excellent hypothesis of Kepler's, in preference to the others, for explaining the motion of the Moon? I answer: since Kepler, in this part, uses many unfamiliar and very difficult things and terms — namely, when he employs unusual equations, partly physical, partly optical — it would first be necessary to elucidate all of these, and so to level the way. For Kepler also supposes, and takes great pains to demonstrate in the *Epitome Astron. Copern.*, that between the Sun and the primary planets, and likewise between the Earth and the Moon and the Sun, there is the closest affinity, as between other magnetic bodies. In consequence, in the bodies of the planets there are certain fibres, directed along a diameter this way and that, perpetually facing the Sun; of these fibres, stretched out along the diameter, one extremity is called by Kepler the sun-seeking [Solipeta], the other the sun-fleeing [Solifuga]. And there are many other unfamiliar things of this kind, which would necessarily have to be explained before one could set about what we intend — and that, on this occasion, would certainly not happen without a great loss of time, and against my purpose.

[Margin: Kepler's hypothesis is difficult to understand.]

[Margin: That there are certain magnetic fibres in the planets.]

Therefore, as I have already mentioned, I chose to explain the motion of the Moon by epicycles, in the Tychonic manner, because I hope that the Tychonic way is better known not only to all practitioners of astronomy whatever, but even to beginners themselves; not to mention that by this route it will be much more convenient to set all those various and unusual lunar inequalities more clearly before anyone's eyes. For the rest, it is all one whether this hypothesis or another

we assume: the matter comes out the same. Let us at last, then, take up the subject itself, and let us also mention the other planets in those respects in which they agree with the Moon, omitting nothing that could serve this purpose of ours.

[Margin: The latitude of the zodiac.]

1. Just as the Sun (or rather the Earth), alone of all the planets, moves in the ecliptic without any latitude, in whatever part of it, and, properly speaking, describes by its annual course the true ecliptic in the heavens,

so all the remaining planets, together with the Moon, move not in the ecliptic but in the zodiac. The zodiac has its fixed limits on either side of the ecliptic, as far as it extends: namely 8° on one side and as many on the other, so that its whole latitude is 16°. The planets never exceed these limits, but run their courses variously within them — not, however, as the Sun (the Earth) does, in the ecliptic or in some circle parallel to the ecliptic, but in an eccentric, or in eccentric-epicycles [Eccentrepicycli], which cut the ecliptic obliquely: that is, on an axis and poles different from the axis of the ecliptic.

[Margin: The planets other than the Sun have their own eccentricities.]

2. Accordingly, since they move in an eccentric and not in a concentric, they also have, for that reason, their own fixed eccentricities, although one has a greater eccentricity than another. This eccentricity is nothing other than the line intercepted between the centre of the Earth, or of the Sun, and the centre of the eccentric; in the Moon it is only the distance of the centre of the eccentric from the centre of the Earth.

[Margin: Why do the planets appear now faster, now slower?]

From this, as also by reason of the epicycles (as will be taught in its place), the planets together with the Moon appear now faster, now slower; and likewise they are now more remote from the Earth, now nearer to it. The point most remote from the centre of the Earth is called the apogee, and the point nearest the centre of the Earth the perigee — that is, in the Moon. The point most remote from the centre of the Sun, on the other hand, is called the aphelion, and the nearest the perihelion.

[Margin: What are the apsides?]

The points of both kinds are also called, by another name, apsides — the highest and the lowest, that is — and, by the Arabic astronomers, the aux and the opposite of the aux [oppositum Augis]. Points equally distant from the apogee and the perigee are called points of mean distance, or of mean remoteness, or intermediate points.

[Margin: On the nodes.]

3. The orbits of the planets, as also that of the Moon, intersect the ecliptic obliquely at two opposite points; and these points, by a special

name, are called the nodes. One of them carries the planet up towards the north, the other carries it down towards the south; hence the former is called the ascending node [evehens], the latter the descending node [devehens]. In the Moon, astronomers call the ascending node the head of the Dragon and the descending node the Dragon's tail. It therefore follows that when the Moon, like the other planets, stands at the very nodes themselves, they are at the same time in the ecliptic; but when they are removed 90° from the nodes, they are then as far from the ecliptic as they can be. This greatest remoteness is in truth the latitude of the planets, or the greatest inclination of the limits. The limits are otherwise called the bellies [ventres]; there are two of them, namely the northern limit and the southern. Their greatest latitude — in the Moon,

that is — extends to 5° when it is within the syzygies [intra copulas]; outside the syzygies, however, it becomes greater by 17′, according to Tycho, but, as Kepler would have it, greater by 18′.

4. The nodes of the Moon lie in one and the same straight line with the centre of the Earth, but they do not always remain in one and the same place. By means of eclipses (which have continually presented themselves in more westerly places of the zodiac) it has been discovered, after some centuries had elapsed, that the nodes move little by little against the order of the signs [in antecedentia signorum], under parallels of the ecliptic, and are restored again to the same point of longitude in the zodiac in, according to Tycho, 18 Egyptian years $223^{d}\ 6^{h}$, so that each day they move backward 3′ 10″ 46‴ 39⁗; according to Kepler, however, in 18 Egyptian years $228^{d}\ 3^{h}\ 50^{m}$. The mean daily motion therefore comes to 3′ 10″ 38‴.

[Margin: On the motion of the apogee.]

5. The apogee of the Moon's eccentric orbit moves in the order of the signs, and is restored to the same point of longitude in the zodiac in 8 Egyptian years $311^{d}\ 6^{h}$. The daily motion of the apogee under the zodiac is 6′ 41″, and the hourly motion 12″.
6. The Moon moves in the eccentric already named, by its own motion, along the course of the ecliptic of the sphere of the fixed stars — and irregularly, with respect to the centre of the world: that is, now faster, now slower. This motion is otherwise called the motion of longitude, or the mean longitude of the Moon from Aries, or from the equinox; and sometimes they also mark this longitude with other names, as

[Margin: On the various names of the longitude.]

namely, as the reasoning requires. For if this motion is referred to the nodes, or to the limits, Kepler calls it the argument, or anomaly, of the Moon's motion in latitude. This is nothing other than the arc of the ecliptic intercepted between the place of the ascending node (or also, for Copernicus, the place of the northern limit) and the true eccentric place of the centre of the Moon's body reduced to the ecliptic; and it is completed in $27^{d}\ 5^{h}\ 5^{m}\ 36^{s}$. The mean daily motion of the anomaly of latitude is therefore 13′ 46″ [recte: 13° 13′ 46″], and the hourly 33′ 5″ (Kepler, *Epitome Astronomiae Copernicanae*, p. 788). But if this motion is referred to the Sun, it is called the equal longitude, or the elongation of the Moon from the Sun; and it is the arc of the ecliptic counted from the mean place of the Sun to the mean place of the Moon in the order of the signs [s. s. s.]. When, however, this motion is referred to the apogee, Kepler calls it the free anomaly [Anomalia soluta], or the inequality of its orbit. The Moon completes this period in the order of the signs with an unequal motion before it returns again to the line of the apsides, after $27^{d}\ 13^{h}\ 18^{m}\ 35^{s}$ of mean motion; and this period likewise varies on account of the monthly inequalities. The

mean daily motion of the free anomaly (as also in the first epicycle) is therefore 13° 3′ 54″, and the hourly 42′ 40″.

[Margin: On the synodic and the periodic month.]

7. For since this motion is counted from some fixed point of the ecliptic, or from the place of the Sun or its opposite point, two different lunar months arise among astronomers as a result: first, the periodic month; second, the synodic month. The periodic month is the span of time in which the line of the Moon's motion, having departed from a given circle of latitude fixed immovably to a definite point of the ecliptic, completes its return and comes back to the same circle. This happens in 27 days and *7.43.5′.8″* hours, by uniform measure. The daily motion is 13° 10′ 33″; the mean hourly motion 32′ 56″ 30‴. The synodic month is the span of time within which the line of the Moon's motion, having departed from the circle of latitude in which the line of the Sun's motion lies (or that of its opposite point), completes its circuit and returns to the same circle. It is also called a lunation, because within this time the Moon's disc is both gradually filled with light and in turn emptied of it. The mean period is completed in 29 days and *12.44.3′.11″* hours. The Moon separates from the Sun each day by an angle of 12° 11′ 27″, and in an hour by 30′ 26″ 37½‴, at the mean rate. And so in a year there are 12 lunations and, beyond these,

132° 45′ of the thirteenth (Kepler, *Epitome Astronomiae Copernicanae*, p. 789). This synodic month, however, is not always equal; but more will be said on this subject later, where some points about the monthly inequalities will also be set out. Now let us go on to speak of the Moon's proper motion.

[Margin: To save the Moon's irregularities, others have devised various epicycles.]

8. Since, then, the Moon (as is clear from what was said earlier) does not move uniformly at all times in its orbit, or eccentric, they at first devised two epicycles to save this irregularity. The first epicycle, namely the greater, they place on the eccentric, so that its centre moves in the order of the signs. [Margin: The Moon's proper motion is explained.] On the circumference of this first epicycle they in turn set up a certain smaller epicycle, namely the second, so that its centre is carried on the circumference of the greater one, but with a contrary motion, against the order of the signs, beginning from the apogee at the upper part — and indeed much faster than the centre of the first epicycle, as will be clear from what follows. Then at last comes the body of the Moon, on that second epicycle; it is again carried round in the order of the signs, beginning from the perigee of the second epicycle, towards the upper part. Since even this does not yet suffice to express the whole motion of the Moon, they therefore devised yet another small circle about the centre of the Earth (to say nothing of the rest, which are reserved for their own place), on which the centre of the eccentric moves. It moves

in such a way that at the time of a true conjunction and of an opposition the centre of the eccentric is always one and the same with the centre of the Earth; afterwards it is moved little by little upwards, towards the right, in the order of the signs, so that at the time of quadrature the centre of the eccentric stands in the upper part of the small circle, at its greatest distance from the centre of the Earth, and so on. Finally, so that all the inequalities might be accurately explained, Tycho devised yet another, smaller small circle on the eccentric, on whose diameter the centre of the first epicycle librates, now towards the left, now towards the right, though with a motion analogous to a circular one; it will be enough merely to have mentioned it here. For a better understanding we shall look at the present figure itself, and explain these circles, epicycles and various motions together; and also

we shall also put before the eyes the position of the Moon both within the syzygies [Copulae], that is, in conjunctions and oppositions, and outside the syzygies; and on this occasion we shall likewise explain all the terms that have been mentioned, and whatever else it is of great importance to know.

Diagram. Hevelius's figure of the lunar theory, set to the left of a narrowed text column. A vertical line runs through the centres of all the circles. At the bottom, a small circle about B stands on the vertical line; above it a large circle, whose upper arc passes through a small circle about F; above that a middle-sized circle centred on F; and at the top a small circle centred on G at the top of the middle circle. The accompanying text calls the large circle the eccentric, the middle circle the first epicycle and the uppermost the second epicycle; the plate itself carries letters only. Engraver's mark at lower right: "Aut. Sc."

- M (top of the uppermost small circle)
- G (on the vertical line, top of the middle circle; centre of the uppermost small circle)
- N (left) and L (right): where the uppermost small circle meets the middle circle
- K (on the vertical line, foot of the uppermost small circle)
- R (left), F (centre), S (right): the small circle on the arc of the large circle, about the centre F
- V (on the vertical line, foot of the small circle about F)
- O (left) and H (right): where the large circle crosses the middle circle
- I (on the vertical line, foot of the middle circle)
- C (top), E (left), B (centre), D (right), A (foot): the small circle at the bottom
- P (left end of the large circle's horizontal diameter)
- [?] (right end of the same diameter): a looped engraved letter, possibly Q
- T (on the vertical line, foot of the large circle)

[Margin: The theory of the Moon explained by a diagram.]

9. The genuine sense of this theory is as follows. (1) A is the centre of the Earth, through which, from the centre B, the small circle ADCE is

drawn. On it moves the centre of the eccentric F, O, P, T, Q, H, in such a way that in all true oppositions and conjunctions it always stands at A; afterwards it is carried upwards through D to C, and it is always placed at that point at the time of the quadratures. (2) The centre F of the first epicycle IHGO at first librates on the diameter RS of the circle RSV, now towards R, now towards S, though with a motion analogous to a circular one, as we said. After this, the centre F of the first epicycle, together with the second epicycle and the body of the Moon, is carried round towards P, in the order of the signs. (3) On the circumference of the first epicycle the centre of the second epicycle KLMN moves in this way: when the Moon is at apogee, the centre is at G; afterwards, with a contrary motion, against the order of the signs, it is carried through L, H towards the perigee I. Each centre, however, advances with a similar course, and in equal times they complete similar arcs, or equal angles at the centres of their motion. Coming to the perigee I, however, it now appears in the order of the signs, upwards as far as the apogee

to advance. So the centre of the second epicycle always advances in the order of the signs in the lower semicircle HIO, and against the order of the signs in the upper semicircle OGH. (4) It is in this second epicycle that the Moon itself is first moved, and in this way. When the centre of the second epicycle is at G, that is, at the apogee of the first epicycle, the Moon is at K, at the perigee, so to speak, of the second epicycle; and this happens in all conjunctions and oppositions. But when the centre of the second epicycle reaches H and O, which happens in all the quadratures, the Moon is at the apogee of the second epicycle. If, however, the Moon is situated between the conjunction or opposition and the quadratures, matters stand otherwise, as will appear more clearly from the following figure; as will this also, that the Moon is never removed from the Earth by the whole distance AM. When the Moon stands at perigee, the centre G of the second epicycle is placed at I, as at the perigee of the first epicycle, and the Moon, with respect to the Earth's centre A, is in the upper part of the second epicycle, at M; this should be carefully noted. The motion of the Moon on this second epicycle is therefore double that of the centre of the first epicycle. This motion, which is completed in that first epicycle, is called by some the anomaly of the eccentric [Anomalia Eccentrici], by the Alphonsines the centre of the Moon [centrum Lunae], and the double longitude, or the doubled distance of the Moon from the Sun; which is nothing other than the measure of the arc of the second epicycle, taken from its perigee K through L to the body of the Moon, in the order of the signs. Therefore, since the motion of the second epicycle is double the motion of the first epicycle, the Moon can also run through this epicycle twice before the centre of the second and of the first epicycle is carried round only once, relative to the line of the Sun's mean motion. Hence it comes about, as already said, that in all mean conjunctions and oppositions the Moon is always seen at the perigee of the second epicycle, but in the quadratures at the apogee of that

epicycle, the point most remote from the centre of the first epicycle, where it also produces greater inequalities and differences of appearance than in the mean conjunctions and oppositions.

[Margin: The proportion of the epicycles and of the eccentric.]

The proportion of the radii of the epicycles and of the Moon's eccentric is as follows: in parts of which the semidiameter AF of the Moon's orbit is 100,000, the radius of the

first epicycle FG is 5800, and the radius of the second epicycle GM is 2900. The radius of the small circle AB is 2174 parts, while RF, the radius of the smaller small circle, is only 40½′. On this proportion of the orbs, the angle of the first inequality is no greater than 4° 58′ 30″ in all full moons and new moons, but in the quadratures it is 7° 28′.

[Margin: Why is the Moon slow at apogee?]

10. From this theory, and from what has already been said, almost all the Moon's inequalities and variations can be understood and demonstrated: for instance, why the Moon appears slower at apogee than at perigee. This arises because the centre of the second epicycle is carried against the order of the signs [in Antecedentia], that is, backwards as it were, as is known, and so is the Moon itself as it runs through the lowest part of the epicycle; and this happens around the apogee or the perigee of the second epicycle. Conversely, when the Moon is at perigee, and the centre G of the second epicycle is in the lower part I of the first epicycle, not only does the centre G of the second epicycle move in the order of the signs [in consequentia], but so does the Moon itself at the same time, and so does the centre of the first epicycle, so that three velocities combine. The Moon must therefore appear much faster at perigee than at apogee. At the points of mean distance the motion appears moderate, because there the circulation in the epicycles neither opposes nor assists the motion of the centre F of the first epicycle; outside these places, however, the motion either increases or decreases proportionally, as can be seen in this larger figure. Second, it is also easily gathered from this why the Moon's diameter appears smaller at apogee than at perigee: namely, because it is then further removed from our eye. How large the diameter is at that time will be shown towards the end of this chapter.
11. To make the matter clearer (since in itself it is rather obscure), I will explain it with yet another scheme. From it one sees not only the Moon's position at apogee, namely at b, but also at perigee, in the lower part, at i; and moreover what the ratio is of the motion of the centres of the epicycles and of the doubled distance, namely m☽, and things of this kind. Indeed, all the variations, cases and inequalities, into this single figure to compress

I could not, because of the confusion of lines. I have therefore omitted the small circle of eccentricity and kept only A, as the centre of the Earth; nor have I drawn the small circle of libration on the eccentric.

Diagram. An engraved plate set into the text, showing the Moon's two epicycles at twelve stations round the Earth. A large outer circle is divided by radii drawn from the centre A; an inner circle about A carries the centre of the first epicycle, and at each of twelve stations a larger circle (the first epicycle) bears a small circle (the second epicycle), with lines drawn from the centre A through the stations. The engraver's line stands at the lower right.

- A (centre): the centre of the Earth
- b (top of the inner circle): centre of the first epicycle at apogee
- i (bottom of the inner circle): the perigee station
- e (several stations: top, bottom, left [?], right [?], upper left)
- k, m (stations at about 11, 10 and 9 o'clock)
- c (stations at about 11 and 2 o'clock)
- d (station at about 10 o'clock)
- g (station at about 7 o'clock)
- h (station between 7 o'clock and the bottom)
- lower right, in script: "Aut. Sculp[?]." (engraved by the author)
- x (stations at about 10 and 11 o'clock, at the right-hand intersection)
- further small letters and marks in the stations at about 1, 4, 5 and 7 o'clock, some possibly the Moon sign: [?]

The line passing through the centre b of the first epicycle — in this figure iAb — marks the line of the apogee, and all the smaller lines in all the figures, drawn from the centre of the first epicycle through the centre of the second epicycle, are likewise lines of the apogee. All the lines passing from the centre A through the body of the Moon, however, show the Moon's true place in the ecliptic. The angle cA☽ or dA☽ (and likewise the rest) is the epicyclic prosthaphaeresis [Prostaphaeresis Epicyclica]. The prosthaphaeresis of the eccentricity I could not draw on this occasion, since we have no need of it at this time either.

12. Finally, many other things would remain to be said, if each and every thing that concerns the Moon's motion and arises from this were what we had set out to treat fully. But that runs counter to my present plan, as I have often mentioned already; and indeed I also think that what has been said briefly here suffices for this Selenography. Nevertheless I shall add a very few things about the inequality of the synodic month, which has already been mentioned in part; for without knowledge of this month it is impossible to understand the following phases correctly.

[Margin: What makes the synodic month vary?]

Accordingly, if these synodic months were in every respect equal to one another, the phases of any lunation would certainly also be quite alike; but the following observations will show more than enough that they vary very greatly. The cause of this variation is the inequality of both heavenly bodies [Sideris], the Sun as well as the Moon, as Kepler puts it. For as regards the Sun: in summer, when it is slow and its motion is around its apogee, the months it gives turn out shorter, because the Moon overtakes the Sun more quickly; in winter, around the Sun's perigee, the months are longer, because the Moon

overtakes the fast Sun more slowly. The second cause, again, is the Moon, since it is slow at its apogee and fast at its perigee. Other things being equal, therefore, it completes more slowly there than here the remainder still left to it to reach the Sun, beyond the anomalistic return [reditus Anomalicus] already completed.

[Margin: How great is the difference between these months?]

When the causes are combined, therefore, with the Sun at perigee and the Moon at apogee, the month is almost 30 whole days (for only 4^h 23^m are lacking); conversely, with the Sun at apogee and the Moon at perigee, the month has only 29^d 6^h 42^m. If we count from quarter to quarter [à Quadrâ … ad quadram], the inequality of the months can be greater. For half a month, from quarter to quarter, can run out to nearly sixteen days, and the other half contract to thirteen and a half days, a little more. The luminaries at apogee, however, make a month 29^d 15^h 7^m long; at perigee, 29^d 10^h 24^m long.

[Margin: What is the synodic month?]

13. Moreover, since the synodic month has been discussed in this place — which is nothing other than the lunation itself, or the time in which all the lunations, or the Moon's illuminations and changes of light, take place from one conjunction to the next — I therefore think it not unfitting, by the same effort, also by means of a certain diagram

[Margin: From where do the changes of the phases arise?]

to explain from where such varied changes in the Moon's light, and its phases, arise, and what the reason for this is. For it is abundantly clear in itself that the Sun, as the source of light, always illuminates about half the body of the Moon; and yet, as experience attests, neither are the phases always uniform, nor does a perpetual full moon come into our view. The reason is that the illuminated half of the Moon is not always turned towards us, except at the time of true opposition, when we see the whole illuminated hemisphere of the Moon; at any other time, never. This will become quite clear from the following diagram.

[Margin: How does the Moon wax and wane? It is shown in a diagram.]

In it A represents the Sun; B the Earth, or rather the true place of our eye; C, D, E, F, G, H, etc., the Moon. For it is quite certain that the Sun at all times illuminates with its rays about half the lunar body — namely the hemisphere that faces the Sun, that is, the part enclosed towards the Sun by the two lines T P and V R. Again, the far side of the Moon, namely P, S, R, is always seen dark and murky, because the rays cannot reach it.

It is also beyond any contradiction most true that from the Earth B we likewise see about half the Moon (if it happens to be illuminated at the time), namely S, R, Q, or the part enclosed by our angle of vision S, B, Q. Since, however, the part this angle encloses is wholly illuminated by the Sun only once in the space of a month, it is therefore never seen whole except at full moon itself — precisely when the lines of vision B Q and B S, running straight forward together with the two lines of illumination T P and V R, touch the

lunar body at roughly corresponding points, as can be seen in figure I. In the opposite figure C, these same lines touch the Moon in almost the same way, but with this difference: the lines of vision B Q, B S run towards the Sun [contra Solem], since we must turn our face towards the Sun, as happens at every conjunction, for instance in figure C. At that time nothing whatever of the Moon's illuminated hemisphere is seen, since it is turned entirely away from us.

In the second figure, following the order of the signs, when the Moon has already advanced a little from conjunction, some part of the illuminated hemisphere then shows itself, no larger than the small part R Q enclosed by the angle R B Q, or by the line of illumination V R and the line of vision B Q. The part P Q is indeed also illuminated by the Sun, but it is not turned towards us enough to come into view. For that reason it has been drawn with plain lines only in all the figures of the Moon, so that whatever is lit by the Sun but cannot be seen by us at all may be noticed the more quickly; the part left bare of lines, however, is always seen.

[Margin: The illuminated part of the Moon grows or diminishes according to the Moon's greater or lesser elongation from the Sun.]

The farther, therefore, the Moon departs from the Sun, the greater the increase of light appears to our eye, because the angle R B Q widens more and more, as can be seen in figure E and in all those following, up to the full moon I. Afterwards this angle decreases in the same proportion as it had previously grown, as is plainly found in K, L, M, N, O. The quadratures occur around F and M, for there the Moon is 90° from the Sun. In both these figures the visible illuminated part appears a little larger than it really ought to be; the reason is that in this diagram the true proportions of the Sun and Moon, as also of the distances of the Earth, Moon and Sun, have by no means been kept. There is therefore no reason to consider these phases in their smallest details, nor does it matter much, provided that the increase and decrease are explained clearly enough in this figure.

To make the matter all the plainer, I have chosen to add yet another figure, to represent the true aspect of the Moon both waxing and waning — that is, how it is placed in the heavens, and how it waxes and wanes in its eccentric. There it is also apparent that the Moon at one time extends its horns towards the left, namely when the Sun is on the right; at another time turns its horns towards the right, namely when the Moon is waning and the Sun is on the left. For the Moon always shines with its horns turned away from the Sun.

[Margin: The Moon's horns face now the rising, now the setting.]

Diagram. A full-page engraved plate showing how the Moon's phases arise. At the top a circle, the Sun, with A at its centre and V and T at the left and right ends of its horizontal diameter. From V and T lines of illumination fan downwards. Below, twelve Moon discs are set round a large circle centred on the point B (the Earth, the observer's eye), from which lines of vision run out to every disc; faint dotted lines in a coloured ink also run from B towards the

discs. Each disc is shaded on the side away from the Sun. The uppermost disc, C, lies between the Sun and B; the lowest, I, lies opposite. Down the left side runs the waxing sequence O, N, M, L, K; down the right the waning sequence D, E, F, G, H. Round each disc except C are engraved the small letters P, Q, R, S.

- A (centre of the upper circle): the Sun
- V (left of the solar circle), T (right of the solar circle)
- C (uppermost disc), with the engraved caption above it: "New Moon" [?]
- O, N, M, L, K (left side, top to bottom); D, E, F, G, H (right side, top to bottom); I (lowest disc)
- P, Q, R, S: engraved round each of the discs D–O
- B (the central point where the lines converge)
- "Prima Quadrat." (along the line from B to M): First Quadrature
- "Quadrat. Vltima." (along the line from B to F): Last Quadrature
- "Plenilunium." (below disc I): Full Moon
- "Phases Lunæ Creſcentes." (up the left side): Phases of the Waxing Moon
- "Phaſes Lunæ Decreſcentes." (down the right side): Phases of the Waning Moon
- "fig N." (lower left): figure N
- "Aut. Sc." (lower right): the author engraved it

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[Margin: The phases of the Moon receive various names.]

Just as the phases of the Moon, then, are extremely diverse according to the Moon's varying elongation from the Sun, so astronomers too have given them different names, for the sake of better distinction. For example, when the Moon is in true conjunction with the Sun, at C, it is then called the Silent Moon [Luna Silens], the New [Nova], the Empty [Vacua], the Thirsting [Sitiens], the Extinguished Moon [Luna exſtincta], the New Moon [Novilunium], the Neomenia, the Interlunium, the Moonless Night [Nox illunis]. As soon as it begins to wax, it is called the Kindling of the Moon's Light [Accenſio luminis Lunæ]; afterwards Horn-shaped [Corniculata], Razor-shaped [Novacularis], Sickle-shaped [Falcata], Curved into Horns [Curvata in Cornua]. When it stands illuminated in half its part, it is called Half [Dimidia], Cut in Two [Secta bifariam], Halved [Dimidiata], Cleft in Two [Bifida], Bisected [Biſecta], Square [Quadra], Squared [Quadrata], Quadrature [Quadratura], Half-full [Semiplena], Divided [Dividua], Divided into Equal Portions [Æquâ portione diviſa], Dissected [diſſecta]. After this, Hump-backed [Gibba], Humped [Gibbera], Gibbous [Gibboſa], Much-humped [Gibberoſa], Gibbous on Both Sides [utrinque Gibboſa], Curved on Both Sides [utrinque Curva], Swollen on Both Sides [utrinque Prætumida]. When it is steeped in full light, it is called the Full Moon [Luna Plena], the All-night Moon [Luna pernox], the Plenilunium, the Immense with its Full Orb [Immenſa pleno orbe], and so on.

In the same way, since this Selenography of mine also abounds in many and various phases, I have therefore thought it necessary to mark each one with a name of its own, so that they might be better distinguished and all confusion avoided.

[Margin: By what names the author has called his phases.]

The phase seen on the very first day after conjunction I name the First and Newest Moon [Luna prima ac noviſſima]; the second, the Horn-shaped Moon [Luna Corniculata]; the third, the Sickle Moon [Luna falcata]; the fourth, the Horn-bearing Moon [Luna Cornigera]; the fifth, the Curved or Horned or Concave Moon [Luna curvata vel cornuta aut concava]; the sixth, the Crescent-shaped Moon [Luna Lunata], which generally receives this name when it is five days old; the seventh, More than Crescent-shaped [pluſquam Lunata]; the eighth, the Adolescent Moon [Luna Adoleſcens]; the ninth, the Young Moon [Luna Iuvenis]; the tenth, the First Quadrature [Prima Quadratura]; the eleventh, the More-than-Bisected Moon [Luna pluſquam Biſecta], or Fresh from Quadrature [à Quadraturâ recens]; the twelfth, the Gibbous Moon [Luna Gibboſa]; the thirteenth, the Moon Rounding into its Orb [Luna in orbem inſinuata], namely at the time of its trine with the Sun; the fourteenth, the Incurved Moon [Luna incurvata]; the fifteenth, the Much-humped Moon [Luna Gibberoſa]; the sixteenth, the Grown Moon [Luna adulta], since around this phase the Moon always appears to the naked eye almost full of light; the seventeenth, the Moon Verging on Opposition [Luna ad oppoſitionem vergens]; the eighteenth, the Full Moon [Plenilunium]. These are the names of all the waxing phases;

the phases of the waning Moon are distinguished by the same names, only in reverse order, with the exception of a few, as will be seen in their place.

Diagram. An engraved plate printed within the text page, between the opening lines and the rest of the page. A ring of Moon discs runs round an oval: at the top the dark discs of conjunction, at the bottom the full discs of opposition, the illuminated part of each disc growing down the left side and shrinking up the right. Every disc is named outside the ring — the waxing phases on the left, the waning phases on the right. Inside the ring the aspects of the Moon to the Sun are named and marked with their signs, left and right, beside a central column of degree figures; the word ASPECTVS [Aspects] is set twice down the middle. Below the ring stands a key of the aspects in three orders, and the engraver's signature. A legend runs up the left side and another down the right.

- Left side, reading upwards: "Phaſes Lunæ Creſcentis." — Phases of the Waxing Moon
- Right side, reading downwards: "Phaſes Lunæ Decreſcentis." — Phases of the Waning Moon
- Above the top discs: "Interlunium." — the Interlunium; inside the ring below them: "Coniunctio." — Conjunction

- Outside the ring, left, top to bottom: Luna prima (the First Moon); Luna Corniculat[?] (the Horn-shaped Moon; the end of the word is overrun by a disc); Luna Falcata (the Sickle Moon); Luna Cornigena (the Horn-bearing Moon[7]); Luna Curvata (the Curved Moon); Luna Lunata (the Crescent-shaped Moon); Luna plu[[ſ/c]]quam Lunata (More than Crescent-shaped [?]); Luna Adoleſcens (the Adolescent Moon); Luna Dimidiata (the Halved Moon); L. à Quadratura recens (the Moon Fresh from Quadrature); Luna Gibba (the Hump-backed Moon); Luna in orbem inſinuata (the Moon Rounding into its Orb); Luna Incurvata (the Incurved Moon); Luna Gibboſa (the Gibbous Moon); Luna Gibberoſa (the Much-humped Moon); Luna Adulta (the Grown Moon); Luna ad Oppoſitionem vergens (the Moon Verging on Opposition)
- Outside the ring, right, top to bottom: Luna Senex (the Old Moon); Luna Corniculata (the Horn-shaped Moon); Luna Falcata (the Sickle Moon); Luna Cornigena (the Horn-bearing Moon[8]); L. Curvata Seneſcen[?] (the Curved Ageing Moon [?]); Luna Lunata (the Crescent-shaped Moon); Luna plu[[ſ/c]]quam Lunata (More than Crescent-shaped [?]); L. à Quadrat. recens (the Moon Fresh from Quadrature); Luna Biſecta (the Bisected Moon); L. ad Quad. properans (the Moon Hastening to Quadrature); Luna Gibba (the Hump-backed Moon); Luna in orbem inſinuata (the Moon Rounding into its Orb); Luna Incurvata (the Incurved Moon); Luna Gibboſa (the Gibbous Moon); Luna Gibberoſa (the Much-humped Moon); Luna Decreſcens (the Waning Moon); Luna ab Oppoſitione recens (the Moon Fresh from Opposition)
- Below the lowest disc: "Plenilunium." — Full Moon; beneath it the opposition sign ☍ and 180
- Inside the ring, each name on both sides, with the central figure between: Semisextile [Semiſextg.] ⊥ (no figure); Decile [Decilis] 36; Octile [Octilis] ✳ 45; Sextile [Sextilis] ✳ 60; Quintile [Quintilis] ⬠ 72; Quadrature [Quadratus] □ 90; Tridecile [Tridecilis] ⬠, with 1½ above the left-hand sign and ½ above the right-hand sign, 108; Trine [Trigonus] △ 120; Sesquiquadrate [Seſquadrus] □ with 1½ above, 135; Biquintile [Biquintilis] 144; Quincunx ⊥ with 5 above (no figure); below these, Opposition [Oppoſitio]
- Centre, twice (one reading upwards, one downwards): ASPECTVS — Aspects
- Key, "Aſpectus primi Ordinis." — Aspects of the First Order: Conjunction ☌ 0°; Opposition ☍ 180; Quadrature □ 90; Sextile ✳ 60; Semisextile ⊥ 30; Trine △ 120

[7]so engraved, with n, on both arcs, read in two copies; the text of p. 245, lines 23–24, prints *Cornigera*

[8]so engraved, with n, on both arcs, read in two copies; the text of p. 245, lines 23–24, prints *Cornigera*

- Key, "Secundi Ordinis." — Of the Second Order: Quintile ⬠ 72°; Biquintile, ⬠ with 2 inside, 144; Quincunx, ⊥ with 5 above, 150; Decile, ⬠ with ½ inside, 36; Tridecile, ⬠ with 1½ inside, 108
- Key, "Tertii Ordinis." — Of the Third Order: Octile ✳ 45°; Sesquiquadrate, ✳ with 3 above or □ with 1½ above, 135°
- Lower right: "Autor Sculpſ." — the author engraved it

[Margin: Names of the phases of the waning Moon.]

The first phase after opposition is named the Moon Fresh from Opposition [Luna ab Oppoſitione recens]; the second, the Waning Moon [Luna Decreſcens], because it now first appears to the naked eye to wane; the third, the Much-humped Moon [Luna Gibberoſa]; the fourth, the Phase of the Incurved Waning Moon [Phaſis Lunæ incurvatæ decreſcentis]; the fifth, the Waning Moon Rounding into its Orb [Luna in Orbem inſinuata decreſcens]; the sixth, the Gibbous Moon [Luna Gibboſa]; the seventh, the Hump-backed Moon [Luna Gibba]; the eighth, the Moon Hastening to Quadrature [Luna ad Quadraturam properans]; the ninth, the Last Quadrature [ultima Quadratura]; the tenth, the Moon Fresh from Quadrature [Luna à Quadraturâ recens]; the eleventh, the More than Crescent-shaped Moon [Luna pluſquam Lunata]; the twelfth, the Moon

crescent-shaped [Lunata]; the thirteenth, the Ageing or Curved Moon [Luna ſeneſcens ſeu curvata]; the fourteenth, the Horn-bearing Moon [Luna cornigera]; the fifteenth, the Sickle Moon [Luna Falcata]; the sixteenth, the Horn-shaped Moon [Luna Corniculata]; the seventeenth, the Old Moon Inclining toward Conjunction [Luna Senex in Conjunctionem propendens]; and the eighteenth is the new moon or interlunium [Novilunium ſeu Interlunium]. These are the phases of the Moon, both waxing and waning, and they take their origin from its varying elongation from the Sun.

[Margin: What is an aspect?]

As for the aspects of the Moon and the Sun, they likewise arise from the elongation already mentioned. They are a definite position and placing of the stars relative to one another in the zodiac, and are otherwise called configurations. The ancients had only five of these aspects: namely conjunction, opposition, quadrature, trine and sextile.

[Margin: How many kinds of aspect are there?]

Kepler, however, devised eight more besides, so that in his view there are thirteen aspects. These are divided into three classes or orders: the first, the second and the third order.

[Margin: Distinctions of the aspects.]

The aspects of the first order are more important and stronger than the rest; they are held to be conjunction, opposition, quadrature, sextile, semisextile and trine. Of the second order: quintile, biquintile, quincunx, decile, and tridecile or sesquiquintile [ſeſquintilis]. Of the third order: octile, and sesquiquadrate [Seſquadrus] or trioctile.

[Margin: What is conjunction?]

1. Conjunction is the aspect in which stars, seen from the Earth, come together in the same place and degree of the zodiac. It is marked with this sign ☌.

[Margin: Opposition.]

2. Opposition is the aspect in which stars, set diametrically opposite with the Earth between them, are separated by a whole half of the zodiac, that is, by 180°. Its mark is ☍. These conjunctions and oppositions of the Sun and Moon are usually also called syzygies [Syzigiæ]; the remaining aspects, by contrast, are called configurations.

[Margin: Quadrature.]

3. Quadrature is the aspect in which stars are removed from one another by a quadrant of the zodiac, or an arc of 90°. Its mark is □.

[Margin: Sextile.]

4. Sextile is the aspect in which stars are separated by a sixth part of the zodiac, or an arc of 60°. It is marked with this sign ✳.

[Margin: Semisextile]

5. Semisextile is the aspect in which stars are separated from one another by a twelfth part of the zodiac, or an arc of 30°; it has seemed good to mark it with this sign ⊥.

[Margin: Trine.]

6. Trine [Trigonus, ſeu Trinus] is the aspect in which stars are separated from one another by an interval of a third of the zodiac, or an arc of 120°. Its mark is △.

[Margin: Quintile.]

7. Quintile is the aspect in which stars are separated by a fifth part of the zodiac, or an arc of 72°. It has seemed good to mark it with this sign ⬠, since a pentagon has that many sides.

[Margin: Biquintile.]

8. Biquintile is the aspect in which stars are removed from one another by an arc of 144°. It equals the sides of the pentagon twice over; that is, it is the aspect in which the stars are separated from one another by twice the interval they have in the quintile aspect. For that reason I have chosen to distinguish this aspect with this sign: ⬠ with a 2 set above it.

[Margin: Quincunx.]

9. Quincunx is the aspect in which stars are removed from one another by 150°, namely by five twelfths [unciis] of the zodiac; or it is the aspect that equals five semisextiles. This sign therefore suits it as well as can be: ⊥ with a figure set above it [?].

[Margin: Decile.]

10. Decile, or semiquintile, is the aspect in which stars are removed from one another by a tenth part of the zodiac, or an arc of 36°. It requires only half the distance of the quintile aspect, and for that reason this mark fits it best: ⬠ with ½ set above it.

[Margin: Tridecile.]

11. Tridecile, or sesquiquintile [Sesquintilis], is the aspect in which stars are separated from one another by an arc of 108°; or the aspect that equals three deciles; or the one in which the stars are removed from one another by three tenths of the zodiac. Mark it, therefore, thus: ⬠ with 1½ set above it.

[Margin: Octile.]

12. Octile is the aspect in which they are separated from one another by an eighth part of the zodiac, or an arc of 45°. It is marked with this sign ✳.

[Margin: Sesquiquadrate.]

13. Sesquiquadrate, or trioctile, is the aspect in which stars are 135° apart. This space equals three intervals of the octile aspect, or one and a half quadratures. You will mark it thus: ✳ with 3 set above it, or □ with 1½ set above it.

[Margin: Another division of the aspects]

The thirteen aspects named above are further distinguished in another way by the most acute Kepler, in book 4 of the *Harmonices Mundi* [Harmoniâ Mundi lib. 4.], namely into five degrees of efficacy. For him the first and strongest degree of efficacy is that of conjunction ☌ and opposition ☍. The second degree in the efficacy of the aspects is that of quadrature □. The third degree of efficacy is that of trine △, sextile ✳ and semisextile ⊥. The fourth degree in the efficacy of the configurations is that of quintile ⬠, biquintile (⬠ with 2 above) and quincunx (⊥ with 5 above). The fifth, last and weakest

degree of the aspects is that of decile (⬠ with ½ above), tridecile (⬠ with 1½ above), octile ✳ and trioctile (✳ with 3 above). More is to be found about these in Kepler's *Harmonices Mundi*, already mentioned.

Up to this point we have spoken briefly about the illumination of the Moon, its various phases and the names of those phases, and also about its various aspects, which arise from the Moon's motion and its varying position with respect to the ecliptic. Now, as a favour also to lovers of astronomy [Aſtrophilorum]: just as I chose to represent those various phases of the Moon, as they appear, in the preceding figure, so I also chose to set down in the same figure the various names of the phases, the signs of the aspects and the arcs, so that, by means of a kind of small table, they may be understood the more readily and committed to memory. Many questions could indeed be raised here about the illumination of the Moon and what pertains to it — above all, why the Moon is never less illuminated than when it is full? — and many others of this kind. But I think these questions should be put off to the place where the lunar phases will be treated specifically later on.

[Margin: On parallaxes.]

It follows that I should pursue further the matters that necessarily concern the Moon, with whose help the varied motion of the Moon, of which we have spoken up to now, is made clearer and so plain to beginners in astronomy that it can be understood even by the less perceptive. Among these the doctrine of PARALLAXES holds not the last place: of all the parts of astronomy it is

the most ingenious. And yet I do not deny that it is also the most difficult part of astronomy of all, because parallaxes cause astronomers no little trouble, especially in eclipses of the Sun — so much so that it seems no wonder at all that many, on account of this great and toilsome labour, have abandoned the study of astronomy altogether. Although indeed the calculation of parallaxes may seem very difficult to a student newly initiated into astronomy, it is nonetheless extremely necessary to him, since without it neither can the motion of the Moon be rightly understood, nor eclipses of the Sun computed, nor the motions and seats of comets explored, nor the true distances and magnitudes of the luminaries investigated — all of which, by means of parallaxes, is otherwise accomplished with the greatest ease and in an infallible way; if only some sensible proportion between the distance of some phenomenon and its distance from the cen-

tre of the Earth to its surface, or between the centre of the Earth and the observer's place, is perceived. For then the true place always differs from the seen place, as happens in the Moon at all times, and in those bodies that never rise higher than the body of the Sun itself.

[Margin: The higher the bodies, the smaller the parallax.]

But in any body that stands higher than the Sun (like those two superior planets) there is no difference between the true and the seen place, since it has no parallax; or if some parallax is still to be found, it will certainly be so small that it can scarcely, if at all, be detected. In Saturn it scarcely equals a third of one minute, according to Tycho's calculation, as he mentions in the *Progymnasmata*, Chapter 6, page 414. In the Moon the greatest parallax of all is observed, since of all the other ethereal bodies it is the nearest to the Earth, and its distance bears no small proportion to the Earth's diameter — so much so that its parallax can sometimes be greater than 60′.

[Margin: What parallax is.]

Parallax, then — or diversity of aspect [diversitas aspectus], called by others *evariatio*, *permutatio* or aberration of sight [aberratio visus], and by Copernicus *commutatio* — is the difference between the true place and the seen or apparent place. Or, to describe it more plainly: it is the distance of the seen place from the true one, and it arises from the line drawn from the centre of the Earth to a phenomenon seen on high and the line drawn from the eye, or from the surface of the Earth, to the same phenomenon. From this definition it is already partly clear what parallax is and where it comes from: namely, from the fact that the celestial bodies are viewed not from the centre but from the surface of the Earth. Therefore in those celestial bodies whose position is not so lofty that the Earth's diameter could vanish altogether in comparison with their distance, a parallax is always found. That is, bodies and phenomena of this kind always appear to us in a different place of the sphere of the fixed stars than if they were observed from the centre of the Earth.

[Margin: The line of the true place and that of the seen place differ.]

Hence it follows that the line of the true place of a phenomenon is one line, and the line of its seen or apparent place another. The line of the true place is the one that runs from the centre of the Earth through some phenomenon out to the sphere of the fixed stars. The line of the seen place is the one that runs from the eye of the observer through the phenomenon out to the starry sphere, as will become clearer from the figure that follows shortly.

[Margin: In the most remote bodies the parallax vanishes.]

First, these parallaxes are so constituted that the nearer a phenomenon is to the centre of the Earth, the greater the parallax it produces; the more remote it is, the smaller; and the most remote, none. This becomes clear not only from the diagram itself but is also amply confirmed by any terrestrial objects whatever. Further, parallaxes are greatest near the horizon, smaller when the star is raised, and nil at the vertex: for when something stands at the point of the zenith, there is no difference between the line of the true place and that of the seen place, and with it the parallax vanishes completely. But first we shall explain this with a diagram, before we turn to the different kinds of parallax.

Diagram. A semicircular construction set between the two paragraphs of the page. A small circle at the bottom centre represents the Earth, with its centre A and its surface point D above it. Three concentric semicircles rise over it: the innermost is marked as the orbit of the Moon, the middle one as the path of the Sun, and the outermost, with B at its summit beneath the word "Zenith", as the circle of altitude. Two horizontal lines cross the base: an upper one through D, labelled as the visible horizon, and a lower one through A, labelled as the rational horizon, ending at C at either corner. From A and from D pairs of straight lines run out through the lettered points F (on the Moon's orbit) and E (on the Sun's path) to the outer circle, where their ends are lettered G, H and I in groups on both sides — the true place and the two seen places — the lines drawing together toward the zenith. The engraver's mark stands below the figure at the right.

- Top centre: "Zenith." — Zenith; B at the summit of the outer circle.
- Outer circle, either side of B and down both flanks: groups lettered I H G (left of B), G H I (right of B), G, H, I down the left side and G, H, I down the right side.
- Outer circle, words along the arc: "Circulus" (upper left), "Altitudinis." (upper right) — Circle of Altitude.
- Middle arc: E at six points; words "Vi[?]" (left) and "Solis." (right) — the path [Via] of the Sun, the second letter of the first word not settled on the scan.
- Inner arc: F at six points; words "Orbita" (left) and "Lun[?]" (right; the ending reads as *-æ* or *-a.*) — Orbit of the Moon. [?][9]
- Lines on the right: "Linea visi loci." — line of the seen place; "Linea veri … loci." — line of the true place.

[9]three of these twelve E/F letters, low on the arcs, are E or F by their form on this copy; the six-and-six count is not settled.

- Upper horizontal line: "Horizon" (left) … "Visibilis." (right) — visible horizon; I at either end.
- Lower horizontal line: "Horizon" (left) … "rationalis." (right) — rational horizon; C at either end.
- Small circle: D (top), A (centre), "Terra." — Earth.
- Below the figure, right: "Aut. Sc." — engraver's mark.

Look: in the present figure the lowest little circle represents the Earth, A its centre and D its surface; the outermost circle CBC represents the hemisphere of the fixed stars; E, for example, the Sun, and F the Moon. If it were possible to view those bodies from the centre of the Earth, they would be seen on one and the same line, as in conjunction — namely at G of the sphere of the fixed stars, which would at once be the true place of both, since the line of vision extends from the centre of the Earth. But since there is no view of these bodies from the centre of the Earth, but only from the surface of the Earth at D, both the Sun and the Moon appear to us among the fixed stars in a place altogether different from the former: the Sun at E, as the more remote body, at H, and the Moon at F, at I.

Each of these is called the line of the visible place, for it is drawn from the surface of the Earth — that is, from the eye — through the place of the phenomenon to the sphere of the fixed stars.

[Margin: Parallax is contained by the line of the true place and that of the seen place.]

Whatever lies between the line of the true place and that of the seen place is therefore called parallax. For example, in this diagram the parallax of the Sun, the higher body, is GH, and that of the Moon F is GI. Moreover, it is evident that the true place of any star or phenomenon is always higher than its seen or apparent place, so that by reason of the parallax of altitude all stars are always depressed more than they should be, just as refractions raise them more than they should — as is plain at G, the true place, and at H and I, the seen place.

[Margin: Parallax raises phenomena more than it should.]

[Margin: From parallax the true position of comets is known.]

Second, it is also true without exception that the higher a body is in the heavens, the smaller the parallax it produces, and the lower it is, the greater. For example, the parallax of the Sun at E is only GH, but that of the Moon is GI, which is far greater. By this invincible argument it is demonstrated to the Aristotelians that comets exist in the ether, and indeed much higher than the Moon itself; and they will never by any means refute this argument, however hard they try.

[Margin: In lower-lying bodies the parallax is greater.]

Third, the nearer such bodies are to the horizon, the greater the parallax becomes; but the farther phenomena are removed toward the point of the zenith, the smaller the parallax becomes, until at last on the vertical line, as here at B, it dies away entirely. Fourth, just as parallaxes in the eastern quadrant decrease more and more and grow smaller as the body ascends, so in the western

quadrant they increase again in the same proportion as it descends. Fifth, one may also see here — as is indeed most certain — that the parallaxes of the planets and the luminaries are smaller in apogee but much greater in perigee, in proportion to their distance from the Earth.

[Margin: In perigee the parallax is found to be least.]

[Margin: The difference of parallaxes.]

Therefore, since there are various kinds of parallax in astronomy, we must certainly touch on how they differ. First, there are six kinds of parallax: namely the parallax of altitude, or vertical parallax; the parallax of longitude; the parallax of latitude; the parallax of declination; the parallax of right ascension; and the parallax of distance, or of different horizons.

[Margin: What the parallax of altitude is.]

The parallax of altitude, or vertical parallax, is the arc of the vertical circle through the true place of the centre of the body of the Moon, or of some

phenomenon — the circle being drawn through that place — intercepted between this true place and the visible place. Or it is the angle contained by the lines of the true and the seen place of the phenomenon.

[Margin: The parallax of longitude.]

The parallax of longitude is the arc of the ecliptic, or of a circle parallel to it, lying between two circles of latitude, of which one is drawn through the poles of the zodiac and the true place of the planet, and the other through the same poles and the apparent place. This parallax always occurs in the circle of longitude, that is, of the star's course.

[Margin: The parallax of latitude.]

The parallax of latitude is the difference between the true and the seen latitude, counted on a great circle drawn through the poles of the ecliptic perpendicular to the former, and enclosed between two circles parallel to the ecliptic.

[Margin: The parallax of declination.]

The parallax of declination is the difference between the arcs of the true and the seen declination.

[Margin: The parallax of right ascension.]

The parallax of right ascension is the difference between the true and the seen ascension, that is, the arc of the equinoctial between the arcs of the true and the seen declination.

[Margin: The parallax of distance.]

The parallax of distance — or of different horizons, or of two positions — is the difference between the two places on the starry sphere at which some phenomenon appears from two distant regions, or from particular cities. Or rather, it is the difference between two seen places, measured by the angle set at the centre of the star.

Diagram. A woodcut set at the left of the text: a circle (the circle of the ninetieth degree) crossed by a horizontal diameter (the horizon) and by intersecting arcs — the ecliptic running from lower left to upper right, a vertical

circle descending from the top, and two arcs drawn from a point at upper left. A small italic mark stands at the lower right of the cut.

- F (top of the circle): the zenith
- G (upper left on the circle): the pole of the ecliptic
- E (upper right on the circle): end of the ecliptic arc
- H (inside, upper centre, on the vertical circle): the true place of the Moon
- I (just right of and below H)
- K (below H, on the vertical circle): the visible place of the Moon
- B (left end of the horizontal diameter)
- C (right end of the horizontal diameter)
- A (lower centre, where the ecliptic crosses the horizon arc)
- L (right of A, at the foot of the vertical circle)
- D (lower left on the circle): other end of the ecliptic arc
- Aut. S. (small italic mark, lower right of the cut)

To make these parallaxes easier to understand — especially the first three — I shall explain them by a figure. Let B G F E C D be the circle of the ninetieth degree; B A C the horizon; D A E the ecliptic; F H K L the vertical circle, or circle of altitude; F the zenith; G the pole of the ecliptic; G H I and also G K circles of latitude. The first of these is drawn through H, the true place of the Moon; the other ends at K, namely at the visible place of the Moon. In this figure, then, H I is the parallax of altitude, which is the difference on the vertical circle between the true

and the seen place. It should be carefully noted here that this parallax of altitude is sometimes called horizontal parallax, namely at the place where it becomes greatest. K I, a small part parallel to the ecliptic and enclosed by the two circles of latitude, is the parallax of longitude, and I H the parallax of latitude. These three parallaxes form the right-angled triangle K H I, whose hypotenuse K H, as already said, is the parallax of altitude; and together with the other two it is sometimes also called the compound or mixed parallax.

[Margin: Theorems of the lunar parallaxes.]

The particular theorems — chiefly those of the lunar parallaxes — from which their nature and properties will become clearer and clearer, are these.

1. When the Moon occupies the ninetieth degree of the ecliptic from the east, it has no parallax of longitude; the parallax extends wholly into latitude, for the circle of latitude is then vertical and is called the nonagesimal.
2. When the Moon passes through the zenith overhead, there is no parallax. But this happens only in the torrid zone; outside it the ecliptic never becomes vertical.
3. Away from the zenith and the nonagesimal, the Moon admits both parallaxes.
4. For those who live in a northern latitude of the Earth, beyond the thirtieth degree of the elevation of the pole, the parallaxes of the Moon's latitude are always southern; the opposite happens in the southern region. Hence it comes about that the Moon's visible northern latitude is always less

than the true, while its southern latitude is always greater than the true, since the parallax continually depresses it towards the south. Therefore, in computing the Moon's latitude in these regions, if the Moon's latitude is northern and less than the parallax of latitude, then a true northern latitude becomes a seen southern one — as large, that is, as the amount by which the parallax exceeds the true latitude.

5. In the eastern quadrant of the zodiac, between the rising point and the ninetieth degree from it, the parallax of longitude is eastern; in the western quadrant it is western. Therefore in the former it makes the Moon's visible longitude greater than the true, and in the latter less, because the series of the signs, that is, the longitude of the planets, proceeds from the west through the south to the east.
6. The greatest parallax of longitude occurs, in the southern signs, below the horizon; at the equinoctial points, at the horizon itself; and in the northern signs, above the horizon.
7. When the Moon is in the eastern quadrant, the parallax of longitude is added to the Moon's true place reduced to the ecliptic; in the western quadrant it is subtracted. In this way the apparent, or seen, longitude is established.
8. In the western quadrant the visible syzygy follows; in the eastern it precedes. The size of this difference must be sought from the variation of the parallaxes.
9. The parallax of altitude is always greater than the parallax of declination and of latitude, which arises from it.

Finally, to explain the last kind, the parallax of distance or of different horizons, let the lowest small circle in the figure set here be the Earth,

Diagram. A woodcut set across the measure. At the bottom a small circle with A at its centre, and B and C on its upper rim close together. Two concentric arcs curve over it: an inner arc carrying three points D, and an outer arc carrying three pairs of points F and E. From B and from C straight lines run through each D to the outer arc, so that each D has an F and an E beyond it — one pair at the top of the outer arc, two pairs on its right-hand side. A small italic mark stands at the lower right of the cut.

- A (centre of the small circle): the centre of the Earth
- B (upper left on the small circle): one observer's station
- C (upper right on the small circle): the other observer's station
- D (three times, on the inner arc, left to right): the phenomenon
- F (three times, on the outer arc): the phenomenon's place among the fixed stars as seen from B
- E (three times, on the outer arc, each beside an F): its place as seen from C
- a small italic mark, lower right of the cut, reading *Aut* and *S.* with a point or a short stroke between them

A its centre, B the position of some particular place or city, and C likewise the station of some far-distant place. Suppose that from these stations two different observers were observing some particular phenomenon. I say, then, that to the observer at B this phenomenon D will appear at F among the fixed stars, but to the other, at C, at E. The difference E F, therefore, is the parallax of two positions, or of different horizons — or rather, the angle D B C,

to which the other vertical angle, E D F, is equal. With these parallaxes, then, matters stand almost the other way round from the parallax of altitude. Near the zenith they are much greater than near the horizon, and the nearer the phenomenon is to the horizon, the smaller the parallax, as the figure shows. With the parallaxes of altitude the contrary happens: for then, too, the apparent distance of the phenomenon from the zenith is always greater than the true one.

[Margin: The parallax of distance is greatest of all at the zenith.]

How the parallaxes just described can be computed in various ways from the doctrine of triangles is not something to be taught in this place. Anyone, however, who delights in these matters and wishes to spend more time in learning them should read Kepler's *Astronomiae Pars Optica*, chapter 9 — where he brings in many things worth noting, and also a parallactic table, which he carried through all the parallaxes of altitude from 66′ down to one minute, that is, from the Moon down to the Sun; book 2, chapter 10 of the *Astronomia Danica*; Crüger's *Uranodromus Cometicus*, in which he also published an excellent parallactic table, given the altitude of the phenomenon and its distance, and so on; and likewise Tycho's *Progymnasmata*. Besides those named, however, a great many others have also constructed parallactic tables of this kind, as may be seen in Ptolemy, Copernicus, Reinhold [Erasmus Reinhold] and others.

Indeed, since the Moon, as we have learned, is perpetually involved in parallaxes, it becomes clear that the Moon's true motion, as well as its aspect, differs considerably from the apparent one. So, for example, the Moon's true conjunction or opposition is one thing and the apparent another, and the two also differ in time by no small amount: sometimes the apparent conjunction precedes the true one, sometimes it follows it, as we have said.

[Margin: The Moon is involved in parallaxes.]

It remains, on the subject of parallaxes, to indicate also how large the parallaxes of altitude are, especially near the horizon, both when the Moon is at apogee and when at perigee, at the time of opposition, of conjunction, or of the quadratures. At the time of opposition and conjunction, when the Moon is at apogee and is 58 semidiameters of the Earth and 8′ distant from us, its horizontal parallax is 59′ 9″. At perigee, when it is 54 semidiameters of the Earth and 52′ removed from us, the parallax is 61′ 39″. But at the time of quadrature, with the Moon at apogee,

[Margin: How large are the Moon's parallaxes of altitude?]

when its distance is 60 semidiameters of the Earth and 36′, the parallax is 56′ 44″. At perigee, however, when it is removed from us by only 52 semidiameters

of the Earth and 14′, the parallax is 65′ 36″, that is, almost 66′. The difference between the greatest and the least parallax is therefore 8′ 52″. In the Sun the difference in horizontal parallax does not exceed 13″, because at its greatest remove the parallax is found to be only 2′ 54″, at its mean 3′ 0″, and at its least 3′ 7″.

[Margin: The parallax of the Sun.]

Anyone who wishes, moreover, to know these parallaxes extended to every degree of altitude and to a number of different distances from the Earth should consult Tycho's table of parallaxes, which he gives in book 1 of the *Progymnasmata*: for the Sun on page 80, and for the Moon on folio 120. For our purpose, what has been said seems amply sufficient.

Let us now turn to refractions, about which a few things must also be said; for this subject, too, is most necessary for making lunar observations correctly, and above all for determining altitudes. It is not my intention, however, to explain dioptrics fully in this place. Among other remarkable things, dioptrics teaches us to make small, far-distant things appear nearer and larger to the sight — by means, that is, of lenses of various kinds; and with the help of the same dioptrics many other excellent things worth noting are shown concerning the business of burning, of painting and of vision. To deal with all of these now, however, would be beside the way, although some things were said about the refraction of lenses in the second chapter, to which I refer the reader. My intention now is only to say something, and that briefly, about the astronomical refractions of the stars and planets and of the other celestial bodies. The ancients, we read, spoke of these long ago, as Ibn al-Haytham attests in book 7, chapter 3, and Witelo in book 10. Yet none of the earlier cultivators of astronomy brought refractions into true and necessary astronomical use, except the most noble Tycho Brahe and the most distinguished Bernhard Walther, and by this they shed more light on astronomy than words can say. For just as without parallaxes, so too with refractions set aside, no true knowledge of the motions of the celestial

[Margin: Some things are set out concerning refractions.]

[Margin: Tycho and Walther applied refractions to astronomy.]

bodies, above all of the Moon, is acquired. Parallaxes depress all phenomena; refractions, by contrast, raise them in the vertical circle more than they should. There is this difference, however: the greatest part of the stars is free from parallaxes, whereas all celestial bodies and phenomena are affected by refractions, unless they are very close to the vertical point, as will be said at greater length shortly.

[Margin: By reason of refraction, bodies are raised more than they should be.]

To make this doctrine, too, clearer, I therefore judge that certain optical and dioptrical theorems and axioms, which are supremely necessary, must be set out first (some of them have in fact already been mentioned above, in the second chapter), since without them what I intend cannot be understood.

1. All rays that pass through any transparent medium, whether rarer or denser, perpendicularly — that is, at right angles — remain unrefracted. By contrast, if they fall at oblique and unequal angles, they are broken; and the more obliquely they fall, the greater the angle under which they are refracted. Witelo, book 2, propositions 42 and 43, and Maurolycus, book 1, page 36.

[Margin: The first optical axiom.]

2. And indeed rays are refracted toward the perpendicular if they fall from a rarer medium into a denser one; but if they pass from a denser into a rarer, they are refracted away from the perpendicular. Witelo, book 2, propositions 45 and 47; Ibn al-Haytham, book 7, number 8; Kepler, *Dioptrice*, axiom 2; d'Aguilon, book 2, proposition 8, folio 120.

[Margin: The second axiom.]

From this it follows that in as many different transparent media as the line of refraction ends in, in so many different ways does refraction also take place; so that through such different transparencies we can never see anything along a straight line, but only along a refracted one.

[Margin: The line of refraction is refracted in different ways in different transparent media.]

That these things are so is not only amply and more than sufficiently demonstrated in optics; the experience of the eyes also bears witness to it. For the sake of better understanding, it will be no trouble to show this, too, to the beginner in astronomy and optics by a figure.

Let H K L G be a certain vertical circle. What is enclosed by this circle and the next one, M B N, is a rarer medium; the space filled all over with dots is a denser medium; and again, whatever lies between the circle D C O and A is a rarer medium. Further, the line A B I is the perpendicular, that is, the ray that falls at right angles on those different media and remains unrefracted.

The oblique ray L B, however, passing through the point of incidence B from the rarer into the denser medium, would by rights be carried in a straight line to F if it were not refracted. But since at point B, entering as it were a denser transparent medium, it is refracted toward the perpendicular P A,

Diagram. A figure of three concentric arcs about a centre A. The outermost, a large circle open at the foot, carries I at its top, K and L to the right of I along its rim, H on the left and G on the right. A horizontal line H B G runs across it, touching at B the top of the middle circle, whose arc carries M on the left and N on the right; the band between the middle circle and the innermost circle is filled with dots. The innermost circle carries P at its top, D and E on its left side and O on its right. A vertical line descends from I through B and P to the centre A. From B, a line rises to K and another to L; a line runs from B down to F on the left on the middle circle, and another runs from B to C on the innermost circle. From C, lines run to D and to E, and a line runs from C to the centre A. A small engraved mark at the lower right of the plate reads "Aut. 8." [?].

- I (top of outer circle): I
- K (upper rim, right of I): K
- L (upper rim, further right): L
- H (left end of horizontal line): H
- B (point of incidence, top of the dotted band): B
- G (right end of horizontal line): G
- P (top of innermost circle): P
- C (on innermost circle, upper left): C
- F (on middle circle, left): F
- M (left, at the middle circle): M
- D (left, at the inner circle): D
- E (just right of D): E
- A (centre): A
- O (right side of innermost circle): O
- N (right side of middle circle): N

it falls on C; and so the line of refraction L B C is formed, with the angle of refraction toward the perpendicular C B F, or its vertical angle K B L. After this refracted ray L B C descends again into another medium — and a rarer one — it is therefore refracted a second time, and, according to the second theorem, away from the perpendicular C A (which is likewise the perpendicular of the point of incidence C), since it passes from a denser into a rarer medium. The line C D is formed, and the angle of refraction is D C E. The angle G B L is the angle of elevation of some object above the horizontal plane, that is, the plane G B H parallel to the horizon. From all this it is evident that if some phenomenon L came into view of someone standing at C, it would not appear in that true place of its own, but at K, the refracted place, which is also the seen place. The true refraction, therefore, will be K L; and in this way an object is raised more than it should be — namely, when rays coming from a rarer medium fall into a denser one — as is evident in the attached diagram.

[Margin: Because of refractions, phenomena never appear in their true place.]

It is in this way with the refractions of the stars and planets. For since it is put beyond all hazard of doubt that our Earth, with a more impure air and material denser than the aether, is packed round, by reason of the various exhalations and vapours that issue from the Earth day by day.

Moreover, the further the air is removed from the Earth, the purer it is; but the nearer it is to the Earth, the thicker and denser it is. From this it necessarily follows that a refraction of the stars must result.

[Margin: The more remote the air, the purer.]

The air, that is, is fittingly divided into three regions: 1. namely, the highest, a little denser than the aether; 2. the middle, which surpasses the former in density; 3. the lowest, the densest of all the others.

[Margin: There are three regions of the air.]

[Margin: The air becomes now thicker, now thinner.]

However, these different regions of the air do not always keep an equal proportion to one another either. Rather, according to the constitution [of the air] and to the exhalations rising, they acquire now one proportion, now another. That is: the middle region of the air may be thicker and denser at one time, and at another — in relation, that is, to the upper air; and the middle may also stand in an entirely different relation to the lowest. As a result, the refraction of the stars is not always equal, even though the stars are observed at a similar distance or horizontal altitude. Nor indeed are the angles of refraction alike at all times and equal in their very proportion, because they are produced by those different regions of the air. Hence that curved line of refraction is not always curved in the same way, nor does it always keep the same section of a circle; rather, for the reasons just given, it becomes instead a conic line, or a parabolic, or a hyperbolic one, according to the increase of the refraction. And this is just what that most distinguished man of rare learning, Master Albert Linemann, Professor of Mathematics at the Academy of Königsberg, laid down — and not beside the point — in a disputation on celestial refractions [de Refractionibus Vranicis], together with the excellent mathematician John Greaves of London.

[Margin: The angles of refraction are not always equal in proportion.]

[Margin: The line of refraction acquires a conic figure.]

In the following diagram, let A be the Earth and B its surface; from B up to C the lowest region of the air, from C up to D the middle region, and between D and E the highest; between E and F the aether; and F some star, whose true altitude is approximately H F. I say that this star F cannot be seen in its true place, but at G, the refracted place, because of the vaporous air surrounding the earth, which is divided into three regions (although, according to the constitution of the air, far more points of incidence still occur). First, the ray from F toward E proceeds, naturally, through the aether unrefracted; but at the surface

of the highest region of the air, at E, it is refracted — toward the perpendicular, indeed — as far as D; then, in the same way, at the surface of the middle region of the air, as far as C; and likewise from C to D.

Diagram. Five concentric semicircles stand on a common base line, with A at the centre of the base. The outermost carries G at its top and F on its upper right; the next carries E; the next D; the next C; and the innermost carries B at its top. A horizontal line runs from the left side of the outermost semicircle through B to H at its right. A broken line runs from F to E, from E to D, from D to C, and from C down to B; short dotted strokes cross the arcs at E, D and C. A straight line descends from G to the lower left, reaching the broken path at C. A small engraved mark at the lower right of the plate reads "Au[t?]. S".

- G (top of outermost semicircle): G
- F (outermost semicircle, upper right): F
- E (second semicircle): E
- D (third semicircle): D
- C (fourth semicircle): C

- B (top of innermost semicircle, on the horizontal line): B
- H (right end of the horizontal line): H
- A (centre of the base line): A

If, therefore, my eye were placed at B, that star would be seen not in its true place F but at G, higher up. It should be noted that in this diagram the refracted place is too far removed from the true place; it was drawn this way for easier understanding. From this, moreover, it is again evident that, because of refractions, all phenomena in the vertical circle appear higher than they should, and no star is found in its true place; rather, stars that in reality lie hidden below the horizon are raised above it for us — which is certainly observed not rarely.

[Margin: By means of refraction we see stars that lie hidden below the horizon.]

Sometimes, too, they show some star motionless above the horizon for a quarter of an hour. The most illustrious Prince of Hesse saw a notable example of this with his very own eyes, and mentions it in a letter to Tycho (Tycho's *Epistolae*, p. 22). That star was Venus, which, raised 2° above the horizon, was seen to be entirely stationary for 15^{m} besides; afterwards, however, it vanished completely in an instant — although in reality, according to calculation, it then lay hidden a full 2° below the horizon.

[Margin: A notable observation of Venus.]

For a similar reason it often happens that, at a true opposition of the luminaries, at the time of an eclipse, we see both luminaries opposite each other and raised above the horizon [finitorem] — by means, namely, of refractions — which would otherwise be impossible; and of these

[Margin: Sometimes, at the very moment of opposition, both the Sun and the Moon are seen.]

spectacles are found here and there, in the ancient as well as the recent authors. Pliny the Elder recorded a twin example in Book 2, chapter 13. The most distinguished Michael Mästlin observed another in the year 1590 July 7. Likewise, a few years ago, an example of the same kind presented itself to a man of the highest learning, our most excellent Mr Lorenz Eichstädt, at Stettin [Szczecin] in Pomerania, in the year 1642 April 15. He mentions it in his small *Ephemeris* for the year 1644 in these words: "As the Sun rose, at the fifth hour and one twelfth of an hour, the Moon, still full in her light, was seen above the western horizon, even though she was in diametrical opposition to the Sun; and she finally set after about two minutes of an hour." So he writes. We too, here in Danzig, witnessed this most delightful spectacle with our own eyes at the same time, in the company of several distinguished men; and perhaps — although I have no certain knowledge of it — it did not escape the sight of others elsewhere as well.

[Margin: Examples worth noting.]

But to continue on our way, let it further be noted that the refractions of the Sun and Moon, as well as of the other stars, at no time extend all the way to the zenith; rather, they die away gradually and vanish entirely at the 20th,

the 30th, or at most the 45th degree, since vapours and exhalations cannot rise any higher.

[Margin: No refractions at the zenith.]

The nearer the stars are to the horizon, the greater the refraction; afterwards, as they ascend, it gradually decreases — though certainly not always in the same proportion, because of the various vapours that rise. Then again, just as refractions change very rapidly near the horizon but only gradually at a higher position, so parallaxes, conversely, remain similar for a long time near the horizon but change more quickly as they approach the zenith. And although refractions vanish entirely near the zenith, it does not follow that no vapours at all are present there; rather, the conclusion drawn from this argument is that in that place the rays pass through those transparent media more directly — indeed entirely unrefracted — and so can produce no angle of refraction.

[Margin: The greatest refraction is near the horizon.]

[Margin: Why do refractions vanish near the zenith?]

Moreover, this property of refractions in the stars must not be passed over in silence either. Even if the altitude of some phenomenon is equal, nevertheless it is not in every place, nor at every

time that the refraction is likewise equal; nor can it be, because of the various exhalations. For this reason, therefore, similar refractions do not always occur in one and the same horizon, let alone in different horizons. This can be confirmed by an example: see Tycho's *Epistolae*, p. 82 and p. 112. For it is more certain than certain that there are many regions in which a far smaller refraction is detected than in these northern parts — for instance in the East, around Alexandria, where for a space of several months scarcely a small cloud is to be noticed.

[Margin: In different horizons, different refractions also arise.]

Furthermore, this too presents itself as worthy of notice in the refraction of the stars: when stars are subject to refractions, their distances in latitude appear greater than their distances in altitude, since the lower of two stars is at any time raised more than the upper, because in the lower the angle of refraction is also greater. For this reason, indeed, the rising and setting amplitude is made greater. Hence too, by reason of the Sun's refraction, we have longer days than they can really be. For through refraction the Sun appears to rise earlier in the morning and, conversely, to set later in the evening, so that it never answers to the calculation; nor can the shortest night ever be compared with the longest day, even in one and the same horizon.

[Margin: Refraction makes the days longer.]

From the same foundation it follows no less that we never have the true equinox and solstice at precisely the time the ephemerides or calendars indicate; for at that time, according to calculation, the days are already longer than they should be, by reason of refraction. If, therefore, refractions were not attended to so diligently and accurately in this matter, the true and proper length of the year could easily be thrown into confusion for us. Further, refraction diminishes the

ascension and the latitude at rising, and the southern declination and latitude; conversely, it increases the descension and the longitude at setting, and the northern declination and latitude. Finally, by reason of refraction the Sun, especially on the horizon, presents an oval figure, so that its diameter of altitude appears shorter than its diameter of longitude. Anyone will be able to infer the reason without difficulty from what was said earlier, especially from what was set out about the parallax of latitude and of altitude.

[Margin: Through refraction the Sun takes on the appearance of an oval figure.]

Finally, it is also necessary to mention how great the refractions of the fixed stars really are, especially the horizontal ones; and whether that of the Sun and of the Moon is the same, or whether a different distance of the heavenly bodies (as with parallaxes) can create a different refraction. Tycho, as I recalled above, was not only the first to bring refractions into astronomical use; he also pursued the matter with great industry and care. With the aid of excellent instruments and through long and assiduous observations, he investigated and recorded the refractions of the Sun and Moon as well as of the fixed stars, and afterwards constructed a table for each degree of altitude, as far as the refraction extended — in a clear sky and a most purified air, and at Uraniborg, indeed.

[Margin: A different distance of the heavenly bodies from the Earth produces no change.]

He found, therefore, the greatest horizontal refraction of the Sun to be 34′ 0″; with the Sun 15° higher, 7′ 30″; with the Sun standing at 30°, 1′ 25″; and when its altitude was 45°, he detected only 5″, after which it vanished altogether. On the same author's authority, the horizontal refraction of the Moon is 33′ 0″; at the 15th degree it is 8′ 0″; at the 30th degree, 1′ 4″; and at the 45th degree it is reduced entirely to nothing. The refraction of the stars is about 4½′ less: for their horizontal refraction is 30′; about the 15th degree, 3′; and at the 20th it vanishes entirely. This refraction, as Tycho holds, can also be applied fittingly to the planets without great difference. Whoever needs these refractions for each degree should consult Tycho's tables of refraction in Book 1 of the *Progymnasmata*. After a careful inspection of that table you will notice that refractions do not depend on the distances of the stars; otherwise there would be a greater difference between those of the Sun and the Moon, as also of the stars. But from where that difference of refractions already mentioned derives, and whether another proportion may also obtain elsewhere — on this there is no good agreement among all astronomers.

[Margin: The amount of the refractions.]

On this occasion you will ask whether there are also several kinds of refraction. Very much so. For they can indeed be divided into different classes, like parallaxes. First, into vertical refraction, of which more than enough has been said. Second, into the refractio-

[Margin: Are there different kinds of refractions?]

n of right ascension. Third, into the refraction of declination. Fourth, into the refraction of longitude. Fifth, into the refraction of latitude. Sixth, also into the refraction of different horizons. All of this will be made clearer by the diagram set beside the text.

Diagram. A woodcut at the left of the text measure: a large circle with two near-horizontal chords meeting it at C (left) and B (right), the lower one bowed down through A; an arc rising from D (lower left) through A, G and F to E on the circle at upper right; and arcs descending from M and from L on the upper rim through H, K, G and F towards the lower part of the circle. A small italic inscription stands at the lower right inside the frame.

- L (top of the circle): L
- M (upper left on the circle): M
- H (upper middle, where the arcs from M and L cross): H
- K (just left of and below H): K
- E (right, on the circle): E
- F (right of centre, on the arc rising to E): F
- G (centre, below F): G
- C (left end of the horizontal chord): C
- B (right end of the horizontal chord): B
- A (lower middle, on the bowed chord): A
- D (lower left, on the circle): D
- lower-right inscription: Aut. S. (engraver's mark; point after *Aut* faint)

The circle BELMCD represents the meridian; BAC the horizon; EFGAD the equator; LHI a vertical circle; MHF the circle of declination through the refracted place of the Moon at H; and MG the circle of declination through the true place of the star at I, so that HI is the refraction of declination. These three refractions likewise form a right-angled triangle, as parallaxes do, whose hypotenuse is always the vertical refraction. But if you take the segment of the circle EFGAD for the ecliptic, and MF and MG for circles of latitude, then again HI becomes the vertical refraction, while HK is the refraction of longitude and KI that of latitude. As for the last kind of refraction, namely that of different horizons: it is the difference in refraction found in two different horizons at the same time, in a clear sky, at equal altitude.

So much, then, on refractions. If what has been said on this subject seems too long-winded to anyone, let him know that I have nevertheless barely touched the least part of it. And if anyone wants further guidance in taking the refractions of any places by various methods, and in determining them both in air and in water, and in subjecting them to calculation, I bid him go to chapter 4 of Kepler's *Paralipomena* to Witelo; to the *Progymnasmata* I, II and III; and to *Apiarium* VIII of Mario Bettini, etc.

It remains, as I promised, towards the end of this chapter, that some further things, and briefly at that, concerning the distance of the Moon from the Earth,

and its bulk, size, and true and visible diameter be set out. This I consider most necessary indeed, both for a right and clear understanding of all astronomical matters and of the lunar phases that follow: for it is for this one reason that a great variety of phases is found, which are to be treated more fully in their place.

[Margin: On the distance of the Moon.]

There is no longer anyone who does not know that the Moon is the lowest of all the planets, as also of the remaining stars, and the nearest to the Earth. But I suspect that its true distance is not known to everyone, since it does not keep one and the same distance at all times: now it is nearer the Earth, now more remote, on account of its eccentricity and epicycles, from which the apogee and perigee have taken their origin. This variation in the Moon's distances the contemplators of the heavens have undoubtedly investigated through assiduous observations of parallaxes, of eclipses of the Moon, and of the shadows both of the Earth and of the Moon; above all, however, the most celebrated Tycho Brahe here made the palm doubtful for all of them, as is clear from the *Progymnasmata*. For he finally found that the Moon at apogee, at the time of conjunction and opposition, is distant from the Earth 58 semidiameters of the Earth and 8′; at perigee, at the same times, only 54 semidiameters of the Earth and 52′; at apogee at the time of quadrature, 60 semidiameters of the Earth and 36′; and at perigee, likewise in the quadratures themselves, 52 semidiameters of the Earth and 14′. So a difference of 8 semidiameters of the Earth and 12′ is found between the greatest and the least distance from the Earth. The ancients before Tycho, such as Ptolemy and after him Copernicus, set down a very different difference: the former 15, the latter 30 semidiameters of the Earth. But since that plainly runs counter to all observations and to genuine reasoning, I shall forbear to say more about these matters, relying on the opinion of Tycho, whose distances answer best to the observations. In Tycho's opinion, therefore, the Moon is never nearer the Earth than 52 semidiameters of the Earth, and never more remote than 60½ semidiameters.

[Margin: That the visible diameter of the Moon varies.]

From this varying elongation, or distance of the Moon from the Earth, the apparent or visible diameter of the Moon also varies. At the time of quadrature, at the most remote distance, its visible diameter appears

to be 32′ 32″; at the time of quadrature, at the nearest distance, 36′ 0″. In conjunction or opposition, with the Moon at apogee, its diameter is 33′ 9″, and at the nearest distance 34′ 48″. According to Tycho's opinion, the difference of the diameters extends to 4′. By what method the visible diameter of the Moon is to be investigated, however, it is not for this place to pursue, since the matter has been treated amply enough not only by Kepler in the *Astronomiae Pars Optica*, chapter 9, but also by the most distinguished Gassendi in his treatise on the apparent magnitude of the Sun when low and when high. Gassendi devised an entirely new method of observing the lunar diameter, and holds the opinion that the visible diameter of the Moon at apogee is only 26′ 36″,

and at perigee 31′ 6″ — a difference that certainly departs a good deal from Tycho's. The Gassendi already praised has gone on to affirm this not only in the second letter of that same treatise, page 41, but also in the *Life* of Pereiskius [Nicolas-Claude Fabri de Peiresc], page 307.

[Margin: The diameter of the Moon determined in miles.]

Now as regards the true diameter, circumference and solidity of the Moon, of the Earth and of the Sun, and also the proportion of the Earth between the Sun and the Moon: 1. If you assume the distance of the Moon from the Earth to be 60 semidiameters of the Earth, and its visible diameter 33′, it follows that the diameter of the Earth (which contains 1720 German miles) is four times greater than the diameter of the Moon, or more accurately by 3 22/49 [?] parts, in the proportion of 2 to 7, or 5 to 17. The true diameter of the Moon comes to 494⅓ German miles, fifteen of which make one terrestrial degree.

[Margin: How great the circumference and solidity of the Moon are.]

Given the diameter of the Moon, moreover, its circumference is also easily found geometrically: namely 1555 5/7 German miles; its convex surface 767,264, and its solidity 63,171,485, cubic miles, that is. From this it appears that the Moon is in fact 42 times smaller than our Earth, whereas the Sun is 5848 times greater than the Moon and 140 times greater than the Earth. But, as Kepler holds, the diameter of the Sun is to the diameter of the Earth as 15 to 1. A similar proportion also obtains between the semidiameter of the Earth and the distance of the Sun from the Earth as between the body, or extent, of the Earth and the body of the Sun. Moreover, just as

[Margin: The proportion of the Earth [?] and the Moon.]

the body of the Earth stands to the body of the Moon, so too the distance of the Moon from the Earth stands to the semidiameter of the Earth, according to Kepler's opinion; and on the claim that the diameter of the Moon's orbit is a mean proportional between the semidiameter of the orbit of the Sun, or of the Earth, and the semidiameter of the Earth, read Kepler on this matter, *Epitome Astronomiae Copernicanae*, book 4, pages 482 and 491. But enough of these things.

CAPUT VIII.

Chapter VIII.

DE PHASIUM LUNAE OBSERVATIONIBUS: de Maculis in specie, & illarum nominibus: Motu Lunæ Librationis Disci, ejusque Centri, hactenus incognito, & quamplurimis aliis scitu dignissimis.

On the observations of the phases of the Moon; on the spots in particular, and their names; on the Moon's motion of libration of the disc and of its centre, hitherto unknown; and on very many other things most worth knowing.

In the preceding sixth chapter we spoke at some length, and as far as need required, about the various opinions of philosophers, ancient as well as more recent, concerning the spots on the face of the Moon. Towards the end of that same chapter we also demonstrated, with cogent reasons, as far as that occasion allowed, that the lunar spots are nothing other than seas, lakes, islands, mountains, valleys and the like, as can be seen there. Let us therefore go on to examine these matters further. We do not doubt in the least that it will, moreover, be far from unwelcome to each and every devotee of astronomy of a generous disposition to learn still more about the observations of the phases themselves, of the spots, and of matters of this kind. For on this occasion other things will be stated, disputed and resolved that are worth noting, most useful, and hitherto unknown; and from them, in my judgement, no small benefit will certainly flow through the whole discipline of the stars.

[Margin: The ancients left no stone unturned to cultivate astronomy.]

Our forebears, indeed, allowed nothing to be found wanting in themselves; rather, they strove with all their strength to enlarge and increase astronomy, the queen of all the sciences, for our sake and that of posterity — just as the sixth chapter above makes more than sufficiently clear how solicitous they were in exploring the true face of the Moon and its spots. But truly, whatever

effort they spent on it, it was in vain. Lacking the means, they tried to look at, observe and contemplate the celestial phenomena with the naked eye alone — which is certainly not enough for distinctly recognizing bodies so far away; and so what they handed down and left to us is in many respects imperfect and uncertain.

[Margin: Galileo, by means of the spyglass, investigated things more certainly.]

But when, a few years ago, that great Galileo Galilei [Magnus ille de Galilæis Galilæus] applied the recently invented telescope to the heavens and, with his eye thus armed, attempted this task, all the labour succeeded far and much more happily, as his *Sidereus Nuncius* bears witness. For, to say nothing of the rest, he not only saw the Moon well and distinctly with his eyes, but by its means was also able to sketch five different drawings of the lunar spots, which shortly afterwards he did not hesitate to share with the whole world in that *Sidereus Nuncius* already mentioned.

[Margin: Galileo did not yet capture the native face of the Moon in his drawing.]

I freely admit, indeed, that this Galileo detected and marked out more in the Moon than all his predecessors — that is, all the ancient astronomers whatsoever. Yet all and each of those who today are likewise not unacquainted with the Moon, and who wish to judge rightly on this matter, will conclude nothing different from me: that this true Lynceus himself (be it said, however, with the leave of that great man) knew only some face of the true and genuine Moon, and by no means noticed the greatest part of the spots and of the things existing there. This, I think, will become as manifest from our figures as what is seen

when the Sun shines as brightly as it can. From this it is plainly concluded that Galileo either lacked a sufficiently suitable spyglass, or could not give enough time to those observations of his, or — and this above all — did not know the art of painting and drawing, which otherwise serves this work greatly, no less than sharp sight, patience and labour. For this work is such that it cannot be completed in a single month or year, but scarcely in very many spans of years. Moreover, it is not enough to draw some particular phase only once; it is certainly necessary to repeat the same drawing several times, if one intends to provide anything certain and corrected in this respect.

Yet would that Galileo and the other searchers of the stars

had published something definite of this kind right from the start! That would certainly have turned out to the great benefit of all astronomy and geography.

[Margin: No selenography has appeared up to now.]

But as far as I have been able to learn at this time, no one has yet come forward who has brought into the open even a single accurately drawn full moon, not to speak of the various phases and a fuller selenography. For although in the year of Christ 1643 Matthias Hirschgarter, in his *Detectio Dioptrica*, showed us some sort of likeness of the Moon to look at — one drawn by a certain Neapolitan nobleman using a tube of superior quality — that sketch can scarcely satisfy anyone. Indeed, that it also departs greatly from the genuine form of the Moon will, I think, appear clearly enough from my figures, to which all exactly made tubes, I know well, will certainly bear witness.

[Margin: For what reasons the author was moved to draw the phases of the Moon.]

When I noticed, then, that very little indeed had been achieved in this business so far — and especially as regards eclipses and occultations of stars, since all those observations (which nevertheless contribute a very great deal to the perfection of astronomy as well as of geography) have not yet been carried out as they either ought to be or could be — I began to weigh this matter more deeply with myself.

[Margin: Without a true drawing of the full moon, no accurate lunar observations are made.]

For when we lack a true and accurately drawn full moon, we certainly lack that solid foundation of these observations without which there is no way at all to duly explore and determine either the true line of the Moon's path in the occultations of stars, or the true magnitude of lunar eclipses — still less the correct proportion of the semidiameters of the Moon and of the shadow — and the other things supremely necessary for cultivating astronomy. Since this is so, I firmly resolved to set about drawing the genuine face of the Moon's visible hemisphere, that is, the whole full moon; and that not in a rough-and-ready fashion [rudi Minervâ], so that we would have merely some sort of likeness of the Moon, but rather with the greatest diligence and effort, as far as my powers would carry it. I resolved also to set before the eyes of all the proportions of

the spots and their distances, as well as their magnitudes and the proper colours of all of them, most diligently attended to and observed. For if even any one of these things were left out, all the labour of our figures would be of little profit, nor much

praise would it deserve — no less so than whatever labour was spent in earlier times on such crude diagrams of the Moon as we have said are extant.

[Margin: By what the author was spurred to undertake the selenographic work.]

But what roused me far more to take up this work even more eagerly were the things that P. Gassendi — by far the most celebrated of men, and one of the highest learning — set down about the Moon in his *Life of Peiresc* [vitâ Pereiſcii]. There, among other things, he recalls that he and that illustrious man Nicolas Fabri de Peiresc [Nicolas-Claude Fabri de Peiresc], senator at Aix and likewise most distinguished for learning of every kind, had intended to observe certain phases of the Moon. Their usefulness, he says, can scarcely be expressed in words, if they are brought to the end hoped for — as one may read at greater length in the *Life of Peiresc* just mentioned, p. 300. These things, I say, for the most part were the spurs that drove me on; especially since at that time I had noticed nothing — not even a single phase drawn by him, let alone engraved in copper. So at first, with my mind thoroughly on fire, I set myself to observe the full moon as accurately as could be done — but certainly not with the aim of making it public. Rather, I meant to take some private enjoyment from it, and in this way to lay, as it were, a foundation for the rest of my observations that were to follow.

[Margin: How the lunar observations were made.]

Before I go on to explain the whole matter further, however, I consider it almost necessary to make plain by what method our lunar observations were prepared. For someone may perhaps imagine — persuaded partly with Kepler, partly with Scheiner — that observations of this kind can be carried out successfully by means of a tube, or of some convex glass fitted to a hole in a darkened chamber, just like, that is, the observations of sunspots. I do not deny that, if this worked so, the method we have described would be the easiest, the most convenient and the most desirable of all that human ingenuity could devise in this matter. For in this way all the shapes and figures of the spots, in their due proportion and distance and in their own colours, would present themselves of their own accord to our eyes on a paper board, so that we could sketch them without great difficulty, just as we taught in chapter 5 how to draw the sunspots;

and it would be a great help toward escaping an immense labour, and a trouble more tedious than words can say.

[Margin: The lunar spots cannot be drawn in a darkened room.]

But this method, believe me, is entirely false, and whoever approaches our work in this way will certainly be disappointed of his hope. For the Moon is plainly not endowed with so vibrant a light as the Sun is, such that it could

carry and project the whole image of its body into a darkened room — except that it is noticed on the paper in some part only, and only so far that merely its figure — that is, whether it is bisected, or horn-shaped, or gibbous — can be distinguished to some extent. For the rest, the spots, both the greater and the lesser, and likewise the boundary of light and shadow, can in no way be discerned like this; rather, they appear like some chaos, or a confused mass, which one can by no means make out distinctly.

It is now asked here, then, with every justification: by what way is it most convenient to approach this business? There is indeed no doubt that for making these observations a sufficiently long telescope of the most excellent quality is required; and the better and more excellent it is, the more successfully and the more perfectly all this can be accomplished. For if in this age of ours we were now without it, and so had to take in everything, as a whole and in detail, with nothing but the naked eye, we would surpass our predecessors little in this respect, and would certainly hardly achieve very much beyond them. It is therefore certain that a telescope is absolutely necessary here. We use it in no other way than simply to look at the Moon through it, just as we usually observe the other stars and the Jovials through the tube, either holding it in the free hand or supporting it on a rest. This can indeed be set up easily; but on the other hand it is a difficult and laborious business to bring certain and well-founded observations, made in the way just described, to the desired end, because we are helped by no special aid or shortcut other than the eye armed with the telescope, and by its measure.

[Margin: With the best telescope the whole face of the Moon is not seen at one time.]

For when we view the Moon in this way, with the aim of drawing what is seen, we are quite unable from the outset to see the whole disc of the Moon at one time with the telescope held still, if the spyglass is a fine and excellent one; indeed, the more excellent it is, the smaller

the portion of the Moon's face that it presents to us, so that in this way one can consider only a part of the Moon and its spots. One then begins from some definite point; next, the surrounding parts, well grasped in the imagination, are at once transferred to the paper set aside for the purpose; and so, in order, you will draw the remaining points, the bays, the mountains and the valleys, at their due distance and proportion, until each and every thing belonging to the Moon's surface has been surveyed, observed and set down in a figure.

[Margin: To draw the phases of the Moon correctly is a most difficult task.]

Put this way, these things may seem not at all hard. Yet they are — it is as certain as anything can be, and there is no reason for anyone to doubt it — truly by far the most difficult, so that one may really say here: *This is the toil, this the task!* [Hic labor hoc opus!] No one, indeed, can understand how great the labour and what kind of diligence this requires, unless he has made the trial with his own eyes and hands — even of a single phase only — without the help of any previous example. For this work demands not only an imagination far the

strongest, and also a tenacious memory, but also singular patience and a mind burning with the most ardent love of observing. Imagination and impression are needed for this reason: so that the things, once seen by the eyes, may cling firmly in the mind until each one has been sketched. Although only the briefest span of time is needed to accomplish this, nonetheless the same thing happens to us here as usually befalls those who contemplate in a mirror either their own face or that of other things. For while their eyes linger on the mirror, they seem to themselves to have taken in everything accurately; yet once their eyes are taken from the mirror, they find that the images they saw barely hover in the mind, faintly and roughly. The same certainly happens in the observations for the lunar figures. As long as we look at the Moon through the telescope, we fully believe that we shall render in lines, by far most accurately and most exquisitely, everything we see. But at the very same instant, when we outline the face and set ourselves to the drawing, we find all too plainly that most things — not to say all — have slipped from memory. It is therefore necessary that every tiny point, ten times or

twenty times, be looked at afresh before the truly proper position of any spot, its figure and its form, can be carried over onto the paper rightly and accurately. Finally, even when we are confident that everything has been duly observed, we nonetheless find, at the second and third observation, that we have grasped things either falsely or not fully, and have been somewhat deceived by appearance.

[Margin: What kind of man the observer of the lunar phases ought to be.]

From this it follows of itself, moreover, that this selenographic occupation demands not only a diligent and patient observer, one who shrinks from no labour and is strong in imagination — of whom you might rightly sing thus, in the Poet's words altered:

Who strives by sight to reach this ethereal goal Has borne and done much, that man; he has kept watch and suffered cold;

— but also a man skilled beyond the common in both drawing and painting. So if an observer lacks either of these, it is almost all over with his observation, and he himself will have produced little of any distinction.

[Margin: Why we cannot use another person's work in these observations.]

For suppose someone wishes to use, as his substitute, the work of some excellent painter, dictating to him whatever comes before his eyes to be viewed on the body of the Moon: that will not be without many difficulties. First, we are scarcely able to hold on to our own thoughts and impressions until each and every thing has been drawn and transferred onto the panel; not to mention that, while everything is being drummed into the painter, much can slip from memory and fail to be passed on faithfully enough. Besides, hardly anyone else will grasp what we ourselves have seen and conceived, however many words we may have tried to paint it with. Add this: if the observer notices that the painter's brush has strayed and has not expressed well what was said, then — even if he is far from weariness and irritation — how will he himself,

unskilled in the painter's art, show the way and the method of correcting the errors or putting something better in their place? Now consider how much attention, industry and patience the painter himself must have. I even affirm on oath that by the most practised and most learned painter no phase will be duly represented the first time; the work will have to be gone over a second time as well, and perhaps even corrected ten times to a nicety. In this way — as anyone understands without my saying it — everything will proceed very slowly. It is also certain that any given phase appears only once

in any given month, and so twelve times in each year; and of these, one or another is not seen even once in its own due time — when, that is, the sky is cloudy.

[Margin: One must keep watch over the Moon every night for observations.]

So one must stay awake every night, and take rest on no clear night: for if a single one is neglected, the phase that was not noticed will scarcely — hardly even scarcely — ever show itself again within the space of one year, or of several. Will the painter, then, be as wakeful through the night as the observer? Or will he not rather be called to the work sometimes drowsy, provided he is still ready and at hand — so that for this reason he will more or less have to be kept and fed in the very house in which the observer, intent on the stars, keeps watch? Consider, then, how many these things are, and that they will bring endless annoyances both to the painter and, far the most, to the observer. And if the painter's work has to be bought, how great an outlay, sufficient for the purpose over several years, will be required? But if some man of ethereal genius, an industrious cultivator of astronomy, himself knows how to use not only his eyes but also his hands — so as to express with the latter on a panel what he has seen with the former — then, because of the noble ardour of his mind, he feels no annoyance and carries everything through eagerly, satisfying his mind no less than his eyes, while he gladly paints with his own hand the stars that the hand of almighty GOD fashioned. This work, therefore, is to be undertaken only by an observer who is at the same time a draughtsman; otherwise the thing will either remain entirely undone, or will be brought about only with the greatest difficulty.

[Margin: At the beginning the author greatly doubted that his observations would make good progress.]

I return to my own observations — those, namely, of which I began to speak above — although about them and their progress I shall go on to mention only a few things. When, then, at the start I began to observe and sketch the full moon, I soon noticed that a great many things, and a wonderful and incredible variety of spots, had to be recorded. At this, certainly, I was not merely dismayed, and hardly lightly, but almost despaired of the success of my whole work: above all because everything had to be drawn only by the measure and judgement of the eyes, and besides, so great an abundance of things presented itself that I did not know which way to turn — whether to begin from this spot or that, or at which to end. Added to this was the fact that these prodigies were wholly

strange to me and until then unknown; above all, since I had no share at all in any phase drawn in any manner whatever, which might, as it were,

have paved the way for me, at least to the proportion of the larger spots. For, to tell the truth, both at the outset of my trials and in my utmost effort, I never saw even a single sketch of the lunar image, let alone possessed one — except, however, those I have already mentioned, whose authors are, namely, Galileo, Longomontanus and Hirschgarter. And although Hirschgarter's seemed more correct than the rest, I was nevertheless led astray by it far more than helped forward, as practice and experience afterwards taught me, with no less loss than vexation. If only I had had the good fortune to receive that lunar diagram from that most excellent man, and also my most highly respected friend, Pierre Gassendi, before I had put the finishing touch to all my phases! Much advantage would surely have come to me from it; indeed, I could have spared myself labours by no means small (not to speak of the gain in time).

[Margin: To draw [?] the true proportion of the spots — this is a matter of skill.]

For at the start the greatest difficulty presented itself in drawing the larger spots, and the more notable places that shine out beyond the others on the Moon, in their true position and natural proportion. At that time no other means were at hand by which one could distinguish these things; one had to rely solely on the judgement of the eye measuring everything — although afterwards I devised certain aids and short-cuts, by far the most excellent (as will be told in its proper place and time), by whose help the proportion of the things to be noted can be established very accurately indeed. And so, first of all, the full moon was drawn after a fashion. Afterwards, however, I noticed very well that it was simply impossible for a correct figure of any full moon, complete in every respect, to be represented from a single session of observation. Rather, these observations must be repeated several times, so that the earlier ones can be reshaped, corrected and brought into better form by the later ones; for in this way the observer becomes more practised from day to day, and is able to notice and discover more and more. But truly, when again and again, because the air was too turbid (as it is all too frequently in these regions, when the days are

very many — indeed, in the autumn, winter and spring seasons certain entire months are very cloudy) the full moon denied me a sight of itself, no small span of time went by before I could draw another figure of the full moon. To this was added the fact that around every full moon a by no means small difference and dissimilarity, compared with the preceding ones, was invariably detected. At first I thought the only cause of this was that I had perhaps been less careful than I should have been in drawing the earlier figures. So I kept correcting the earlier drawings; and although they had already been drawn with the pen as carefully as could be, I rejected them entirely and made others. For I would never have persuaded myself that something else lay hidden here, and that everything depended on a definite motion of libration — which was

not noticed at first, because none of the old philosophers ever held anything other than that the Moon perpetually turns one and the same face towards us (which was discovered only afterwards).

[Margin: The author resolved to investigate the motion of the Moon's libration.]

When at length I had been made abundantly certain of that principal variation, which above all deserves to be observed in the Moon, I began to turn over in my mind and thought how this so supremely necessary matter was to be investigated — that is, how the limits of the libration and its period might be detected. I felt myself carried towards this pursuit (I confess) by a singular eagerness, desire and impulse of mind, and all the more because none of these things had ever been explored before, let alone determined. At the outset, however, I reckoned that it would be impossible, by full moons alone (of which only the smallest part in a year would be visible), to bring this business to completion except over the course of a great many years. I therefore firmly resolved both to contemplate each and every phase of the Moon accurately, and to draw and paint them as exquisitely as was in my power — no less, certainly, than the full moon itself — so that I might at the same time come to know thoroughly the various changes of all the phases, concerning both the sizes of the spots and the boundaries of light and shade. I relied on the sure hope that in this way an opportunity would present itself to me, and the greatest and best means,

of exploring and uncovering many things concerning the phenomena of the Moon that have so far escaped us. And this hope has certainly not deceived me in the least.

[Margin: What size of diameter the author adopted for the phases.]

For the diameter of the lunar phases to be drawn, I had intended to adopt one no larger than about four Rhineland digits, so that too much labour would not arise for me from it — labour that would be greater the larger the size of the figures, as is easy to guess. But finding that each and every detail could not be depicted at so small a size, I chose a larger diameter for drawing the phases. It stands in proportion to the Rhineland fortification foot, or ancient Roman foot, as 628 to 1200; or to the Paris royal foot as 628 to 1266; or to the Danzig foot as 628 to 1096⅘. Nor need you be surprised, kind reader, if on examining this proportion you find all the figures, or their diameters, a little smaller.

[Margin: Paper, when moistened, expands; when dried, it contracts.]

For you should know that paper, when it is moistened for printing, expands because of the moisture, and afterwards, when it dries, contracts again — and indeed not always in equal proportion, whether in length or in breadth, since paper of one kind is subject to greater expansion and compression than paper of another kind. Our own paper, on which the copper figures have been printed, has contracted by ten small parts in breadth, reckoned in the Rhineland foot, but by only six parts in length; and this generally happens to paper of every kind, that it shrinks more in breadth than in length.

[Margin: Because of the contraction of the paper, the round shape of the phases comes out oval.]

Hence all the figures that are most exactly round on the copper plates themselves become oval in shape through the printing; and all the other things contained within the circle take on their shape in that same proportion. It would indeed be desirable for the matter to stand otherwise; but since this variation is very slight and scarcely noticeable, it does hardly any harm. Moreover, if our figures had to be copied by someone a second time and engraved in copper, they would certainly be much corrupted, because that single earlier defect arising from the contraction would be doubled; so that the proportion of the spots and of the distances would be thrown into complete disorder, and rendered faulty. For although the outermost limb of the Moon could be drawn round again, it does not follow from this that the things it contains have also been brought back into their proper shape. I report this so that no one may perhaps think that the observer committed an error in the drawing, but rather that this defect — if indeed it deserves to be called one — always arises from the nature of the paper.

But let us now leave these matters and return to the observations of the phases. As I mentioned before, I undertook observations not only of the full moons but also of the other phases occurring on each single day; and in time these too were happily brought to completion. I was indeed of the opinion that this work could be finished in three or at most four months; but that hope deceived me by far, for I had to spend about as many years on it. For, in the first place, a number of cloudy and less than clear nights were the reason why very many phases — indeed the greatest part of them — could not be observed, so that in the first three or four months I certainly drew very few. Afterwards, when I had already collected not a few phases and was subjecting them to examination month by month as the months followed one another in order, I found again and again that something had been left out here and there that necessarily needed correction. But since the face of the phases rarely appeared alike to itself in every respect, and far more often a great variety and a remarkable alternation presented itself to view, these things left me almost as perplexed as the full moons themselves had done. For although I clearly noticed that all of this arose from that new librational motion, it nevertheless did not become known at once from where, how and at what time the Moon moved, now against the order of the signs, now in the order of the signs, now from the upper part — that is, from north to south — now from south to north. The cause was that, because the sky was very frequently veiled with clouds, it was not possible to observe the Moon properly. Although one phase or another had already been sketched, it soon happened nevertheless that not infrequently at another time they could not be seen; so that, before another lunation came round, the phases had been changed by that motion. And therefore it was not granted so suddenly … any monthly or annual variation of the Moon

to be detected as continuous, since their series was interrupted, and above all since the horn-shaped phases gave me a great deal of trouble.

This drove me to treat these phases too, drawn as they had been in whatever way (although I spared no effort in working them up the first time), by correcting some of them more and more from day to day, and rejecting others altogether and substituting others in their place; so that the number of all the figures drawn at one time or another came to exceed one hundred. Had I not done this, I would certainly not have achieved anything corrected and certain as regards the proportion and distance of the larger as well as the smaller spots, and the full moon itself.

By means of these observations, so frequent and indeed entirely continuous, I succeeded — as with the rest, so above all with the two primary, or general, figures of the full moons — in perfecting them by far most happily: the first, namely, to serve for the phases, lunations and other observations; the second, to serve hereafter for full moons and eclipses. In these primary delineations already mentioned, which I shall present in chapter 44, figure T, the true proportion and distance of all the spots visible on the Moon has been observed with the greatest accuracy and diligence, and has been constructed with bare lines only, without regard to shading. This, unless I am mistaken, is certainly an excellent invention and a very great shortcut for drawing, examining and correcting full moons and phases of every kind — as I in fact found by experience; for had I not devised such figures, it would have been necessary to spend far more time still on this work, and to take on far greater labour.

[Margin: A general delineation of the phases is altogether necessary for the observations.]

However, once these primary figures had been constructed in this way, I set about straightaway weighing and correcting the remaining phases, and those that did not pass on every point I discarded entirely, always, as was said above, trying others.

Now, so that any lover of astronomy [Astrophilus] may likewise draw one phase or another for himself, if he wishes, I shall not be at all reluctant to show at this point, at the same time, how I myself set about this work. First, I had the primary delineation of the phases at hand — not, indeed, the one printed from the copper plate that is attached at chapter 44 (for this, because of the paper's

[Margin: How should the observation and delineation be undertaken?]

expansion and contraction, is less suitable), but a similar one, drawn very accurately with the pen; and following this one I traced in graphite [plumbago], and indeed by this shorter route. With the compasses I drew a circular line equal to the circular line of the primary delineation; on it I laid a blank sheet on which the figure was to be drawn, and fixed the centres together with a needle driven through, while the whole sheet was also pinned down with small pins so that it could not shift in any part. Afterwards I laid these two sheets, joined in this way, on a well-polished glass and turned them toward the light

of the Sun or of a candle; this done, everything could be drawn distinctly and excellently on the lower face with a stroke of lead [galena].

With this figure carefully drawn, I set about making the observations. By its help, namely, the position, proportion, distance and shapes of the spots were already set down, so that it was necessary, first, only to draw the boundary of light and shadow — which was easy to do from the spots themselves — and, second, only to attend to the colours of the spots and to whatever needed to be added or corrected in them. Then, once an observation of this kind had been sketched from the actual face of the Moon, I transferred it again, by exactly the method just described, onto another sheet, so that the phase already observed might be drawn again more accurately with the pen. This is the method I always used from then on for all observations and phases whatever.

[Margin: An immense labour, to draw the phases correctly.]

How great a labour this was I leave to everyone to judge: for not only were the observations watched over every single night, with several hours given to them, but also such varied and all but innumerable phases — certainly several hundred of them — were drawn by hand and pen so accurately that they yielded nothing to printed ones; especially since some of the phases required a span of five, six or seven hours.

Taught thus by experience, I readily grant this to Christoph Scheiner, who records in *Rosa Ursina* that he overcame incredible trouble in preparing his solar observations. But truly, although that work of Scheiner's was both very difficult and troublesome, yet in comparison with our selenographic work I have no fear in saying that it was both more bearable and easier; since ten, or even more, periods of the

solar spots I would rather record and put in order than describe a single lunar phase. For any observation of the solar spots acquires its proper arrangement and proportion right at its first delineation, whereas the lunar phases must be drawn, examined and corrected countless times and continuously every single month, and by far most often built up anew.

[Margin: As the author drew the phases himself, so he also engraved each and every one of them on copper with his own hand.]

To say nothing of that very great labour: I engraved each and every phase, the remaining figures, and all the observations (except only four or five) with my own hand — and that not by using aqua fortis but with the burin [caelum]. How much time, patience and bodily strength, and above all eyesight, was spent on this I shall not say, lest I seem (which I should least wish to be) a vainglorious boaster of my own achievements; I leave it to those skilled in such craft to explain.

Although at first I had wished to have at hand some highly practised and experienced engraver to take on this work, so that I could have been relieved of that mechanical task, yet I was all the less willing to shirk it, the more I was warned — not only by those who knew of my undertaking, and by men most learned in astronomy — not to entrust the phases I had observed lightly to any

engraver to cut into copper. For even if he were very capable in his art, he could hardly, indeed scarcely at all, understand the conception of my eyes and mind as I described it to him in words or drew it out for him beforehand in lines — not to say achieve it with his hand. As a result he would, in the shading, go astray now in one way and now in another, or neglect the proportions, or commit some other fault that could not conveniently be polished away or put right. They also added that no one would apply himself to these matters more intently than I, their author and promoter, who hold them most at heart and in my care. Moreover, I could gather for myself that I would not easily be satisfied by anyone — I, to whom (be it said without boasting) these things were very well known, and to whom the figures to be transferred from the apprehension of the eyes and mind were most familiar from very many contemplations and observations of the Moon itself.

Partly, therefore, persuaded in this way, partly led by my own inclination and

compelled, I finally resolved to engrave with my own hand each and every phase as it is seen in this book. Yet I do not deny that, had I foreseen at the threshold of the work that this burden would have to be borne by me alone, and that I could not easily admit a partner's hand, I would either have abstained from the undertaking entirely or girded myself for it with greater dread. The engraving [Cælatura], indeed, cost me almost as much sweat as the contemplation of the stars. What of the fact that I could also have kept privately hidden away, for myself alone, things finished with so much labour? But a certain impulse, and the consideration of so great an undertaking, drew me another way. For I persuade myself that once this little history of the Moon is shared with the world, universal philosophy will be greatly increased and adorned, whether wholly or in part, as regards the doctrine of the Moon and the heavens — as that supreme and most ingenious hero Francis of Verulam [Francis Bacon] attests, who excellently set out his view on this in the *Novum Organum* [Novum scientiarum organum]. There was also the encouragement and spur — neither infrequent nor ordinary — of very many men who carry great weight with me in both learning and authority, urging that, for the greater benefit of astronomy and the delight of many, I should not be unwilling to come before the public with my observations and figures. So let the die be cast; and (although I am busy enough with other affairs, public as well as private) I shall show how ready I am, to the best of my slender powers, to serve those who look upon and admire the Moon and the whole heaven.

For I have also weighed this carefully in my mind: that all men are bound to put out among others, and to the present and later ages, the talent that God has granted them for a definite end (as we are taught by the parable of the Saviour, our heavenly Master) — above all where those things are concerned by which minds are raised and roused more and more to the contemplation of the wonderful works of God, and occasion is given more and more to praise, celebrate and adore the Creator of these things.

[Margin: The manner of engraving the author chose.]

But, to return to where I left off: know that in drawing these 40 phases and faces of the Moon, and likewise in engraving them, I chose a manner of shading and darkening [adumbrandi & obumbrandi] by which all the very greatly diverse colours seen in the Moon — both insofar as they arise from the marshes and waters, and insofar as from … of differing height

mountains — I could adequately express, and imitate each of them well. Accordingly I cut the larger spots, which present the appearance of waters, into the copper with double transverse shading lines; I surrounded the mountains and valleys with lines; and the summits and peaks of the mountains are enclosed in circles, for this purpose, namely, that they might be expressed better and more luminously. All this could indeed have been drawn with less labour, without lines drawn all round, and with simple shading lines alone. But, as I said, it seemed that in this way everything, as a whole and in each particular, could be represented more accurately and more carefully for all who cultivate astronomy; and so I held to that view.

But lest anyone imagine that I could not carry this out in another way, here is a full moon cut into the copper in bare lines alone. Other, larger ones of the same kind will follow very shortly, as pleasing as can be to the eye and at the same time scarcely lacking in accuracy; more will also be said about them a little later.

[Margin: Although at first sight the phases may seem to someone to waver, the author is nevertheless not to be accused of negligence at once; rather, everything must first be properly examined.]

That in the figures [Iconismi] one valley does not keep the same proportion as another, nor present an equal round shape, nor is shaded alike or drawn with a like shadow, did not happen by chance: believe me, everything was portrayed in this way with the greatest diligence and care — according, that is, to the Moon's natural face. But why certain valleys seem now to widen and now to contract, and that by reason of the shadow, and to be now darker and now brighter; and then why the larger spots do not always keep one and the same appearance, both in shape and in colour — this I shall explain in a more suitable place.

[Margin: It is easier to speak than to act, to pick at praiseworthy things than to accomplish things worthy of praise.]

I would venture to wager that whoever, at the first approach, sees that the spots in our figures of the phases are not all drawn alike will put it down to the carelessness and negligence of the observer and the engraver. But whoever thinks so certainly rushes headlong in his premature judgement. Let him first read what we have said on this matter, and what will be said hereafter. Then it will be right not only to pick at these works of ours, but also to take the tube and the heavens in hand and make trial whether he can handle both better, observe more accurately with his eyes, express more correctly with his hand,

and share it with us. Perhaps, however, more people will rise up whom these works of ours do not please, nor

Diagram. A full-page engraved plate of the full moon: a large shaded disc in fine parallel hatching, showing the dark spots, the bright areas, many small bright spots and craters, and bright rays running out from a brilliant spot in the lower part of the disc. Two graduated rings of nearly equal radius but slightly different centres surround the disc and cross each other at left and right; each is divided and numbered at intervals of ten, the figures increasing counter-clockwise. An engraved title stands at the upper left; the figure letter is at the lower left and the engraver's signature at the lower right. The lower quarter of the leaf is blank.

- Title block (upper left): "PLENILVNIVM." — Full Moon; "Circa Nonagesimum," — about the nonagesimal; "Obſervatum." — observed; "GEDANI." — at Danzig.
- Lower left: "Fig. O."
- Lower right: "Autor Sculpsit." — the author engraved it.
- Ring numerals, counter-clockwise from 10 (each figure set just inside its own ring; those at the bottom stand upside down). Ring A, the outer ring across the top: 10, 20, 30, 40, 50, 60, 70, [?]0, [?]0, 100 (set outside both rings where they cross at the left), [?][?]0, [?][?]0, [?], [?][?]0, [?], 160, 170, 180 or 160 [?], 190, 200, 210, 220, 230 or 280 [?], 240, 250, 260, 270, 280 (set outside both rings where they cross at the right), 290, 300, 310, 3[?]0, 330, 340, 350, 360. Ring B, the outer ring across the bottom: 10, 20, 30, 40, 50, 60, 70, [?]0, 90, 100 (outside both rings, left), [?][?]0, [?], [?], [?][?]0, [?], 160 [?], 170, 180 or 160 [?], 190, 200, 210, 220, 230, 240, 250, 260 or 360 [?], 270 and 280 (both outside the rings, right), 290, 300, 310, 320, 330, 340, 350, 360 or 300 [?]. The figures marked [?] stand on the soft left edge of the plate or in dark hatching and were not read; none has been supplied from the sequence. Where labels stand outside both rings, ring A or B is assigned by position only.

Blank page: the back of the full-moon plate, with the engraving showing through in mirror image.

will they, for all that, labour to please us more by their own trials and by publishing more correct works. For I too grant that better things than mine can now be produced, since I have made my way through these trackless places, overcome many rough stretches, and laid down a more convenient road. I was once without phases; whoever wishes to surpass us will have them from us.

As for the dark and shadowed part of the face of the Moon, waxing as well as waning: why have I not shown it as entirely black? The reason is that darker lines of that kind would completely swallow up and smother those brightly lit points, so that they would be seen less distinctly and accurately. I therefore deliberately shaded that whole space which is not exposed to the Sun's rays with no lines at all, so that nothing could confuse it. Those points of very small size, the little semicircles or little half-moons that are visible outside the

limit of the illuminated part, are, as we said above, the ridges and summits of the mountains; since these are higher than the other parts, they are lit by the Sun's rays all the sooner. The bays, however, and those winding places that stretch out here and there into the brighter part of the Moon, although they are left entirely white in these phases of ours, are nevertheless in reality black and wholly without light, and belong to the outer, less illuminated part, as is easily gathered. I point this out so that no one may perhaps imagine the contrary for himself.

So far we have spoken of the observations of the Moon's phases in general. It follows that we now go on to set out some things in particular about the spots and their properties, and about the motion of libration itself, as I resolved to do in this order. For that reason, at the very entrance, I shall set before students of the stars [Astrosophi] a full moon in a larger format, correctly proportioned, appropriately coloured and drawn as a ground plan [Ichnographicè], so that by means of this figure they may more easily and more happily form some idea at the outset, and acquire a sufficient conception of the Moon, for grasping and understanding what follows more readily. Concerning this full moon, however, I think it should first be pointed out that all those places that are plain white, or coloured with very fine lines, are mountains, valleys or plains; which, as in the preceding sixth chapter,

[Margin: The brighter places of the Moon are valleys.]

was partly demonstrated, and will also be demonstrated more fully in due course hereafter, are certainly there. Those places, on the other hand, which you see evenly shaded with darker lines represent the appearance of the larger lunar seas, marshes and lakes. The rest, however, that must further be said about these things must necessarily be put off until their own names have first been given to all the parts, as it were, of the Moon — namely the seas, bays, islands, continents, peninsulas [Chersonesi], promontories, lakes, marshes, mountains and valleys — by which they may be distinguished; so that, in the description of such varied things, which is to follow very shortly, everything may not fail to be explained more distinctly. This reason too seems weighty enough to explain why we wished, and were obliged, to call all these places by their own particular names; besides it, however, another is still at hand.

[Margin: Why the lunar spots have been given names.]

For it is already clear from the foregoing that, in bringing these observations of ours to light, and above all in placing the face of the full Moon before everyone's eyes, we are also aiming and striving at this: that any observations whatever, of lunar eclipses as well as all the others concerning the Moon (which certainly matter a great deal for the sake of learning), may in future be undertaken and completed by all practitioners of astronomy more accurately and more expeditiously than hitherto. If these observations, then, are to tend to the benefit and growth of astronomy no less than of geography, it is altogether necessary that they be made at the same time by many observers here and there, situated in different places, and compared, and that each should not fail

to open and disclose to the other the things he has noted himself and detected in studying the Moon. This will certainly be very difficult, and all but wholly impossible, unless all the places of the Moon have some nomenclature of their own. Otherwise more time will have to be spent in describing the places to be designated than was spent in observing them, and even someone using the most expansive language would hardly be understood, and would satisfy scarcely anyone. What is more, six hundred errors would easily spring up from it.

For just as the whole of geography too, with all its most ample descriptions and commentaries,

This page is blank; the engraved plate on the other side of the leaf shows through in mirror image. The page carries a later handwritten page number, "222", at the head.

Diagram. Fig. P, a double-page engraved plate of the full Moon, of which this page carries the left half; it continues on the facing page. The lunar disc fills the right of the leaf, its maria shaded with dense parallel hatching and its brighter regions, craters and ray systems left light; no place-names are engraved on this half. Two graduated rims, each a chequered band numbered in tens, run round the limb of the disc and cross each other near the 100 and 280 marks — the two limits of libration named in the title. At the top left two flying putti hold up a cloth bearing the title; one of them carries a branch. At the bottom left two putti measure with a pair of dividers on a board, above a scale bar of German miles.

- Title on the cloth, top left: *The Natural Face of the Full Moon, with both limits of the libration of the disc, the least and the greatest (observed accurately as never before), drawn and engraved in copper by Johannes Hevelius, in the year 1645.* [NATIVA LVNÆ PLENÆ FACIES Cûm, Diſci librationis minimæ et maximæ termino utroque, ut antehac nunquam accuratè obſervata, adumbrata ærique inciſa, per Johannem Hevelium. Ao. 1645.] The words "observed accurately as never before" are set off by large engraved curved brackets.
- Caption, bottom centre: Fig. P.
- Scale bar, bottom left: "German miles" [Milliaria Germanica], numbered 10, 20, 30, 40, 50, 60, 70, 80, 90, 100.
- Rim that is outer at the top, numerals from top right round to bottom right: 3[?] (cut at the fold), 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210.
- Rim that is inner at the top, same order: 3[?] (cut at the fold), 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210. The two rims cross near the 100 mark, so below it the first rim runs inside the second; the two 100s are set side by side outside both rims at the crossing, one for each rim by position.
- A small lettered construction at the right edge, mid-height — about nine small italic letters strung along fine straight lines; whether engraved or added in pen is not decided: [?].

Diagram. The right half of Fig. P, continued from the facing page. The disc's two graduated rims continue round its right-hand limb. At the top right two flying putti hold up a second cloth, engraved with a quotation from Seneca; one putto carries a branch. At the bottom right a standing putto looks through a telescope and holds a graduated staff, while a seated putto writes in a book; beside them stands a globe. Beneath them is a scale bar of ecliptic digits.

- Quotation on the cloth, top right: *Nature does not hand over her sacred things all at once: those mysteries are not open indiscriminately, nor to everyone; they are withdrawn and shut away in an inner sanctuary. Many things are reserved for ages still to come, when the memory of us will have faded. Of these, this age will see one thing, and the age that follows us another. When, then, will these things be brought to our knowledge? Great things come slowly — especially if labour ceases. Seneca, Natural Questions, book 7.* [Rerum natura, ſacra ſua non ſimul tradit. Illa arcana non promiſcuè, nec omni bus patent: reducta & in interiore ſacrario clauſa ſunt. Multa ſæculis tunc futuris cùm me- moria noſtri exoleverit, reſervantur. Ex quibus aliud hæc ætas; aliud quæ poſt nos ſubibit, aſpiciet. Quando ergo iſta in noti tiam noſtram perducentur? Tardè magna proveniunt; utique ſi labor ceſsat. Senec. lib. VII. Natur: Quæſt.]
- Scale bar, bottom right: "Ecliptic digits and their parts" [Digiti Ecliptici, et eorūm Segmenta], with the large numerals 1, 2, 3 above it and the small numerals 30, 60, 30, 60, 30, 60 along it.
- Outer rim, numerals from top left round to bottom left: 4[?] (cut at the fold), 30, 20, 10, 360, 350, 340, 330, 320, 310, 300, 290, 280, 270, 260, 250, 240, 230, 220, 210.
- Inner rim, same order: [?] (cut at the fold), 20, 10, 360, 350, 340, 330, 320, 310, 300, 290, 280, 270, 260, 250, 240, 230, 220, 210. The two 280s stand outside both rims where the rims cross; the 210 that ends each list is the facing half's 210 seen past the fold, not a second engraving.
- A small lettered construction on the disc at the left edge, mid-height — about four small letters along fine lines, perhaps continuing the one on the facing half; whether engraved or added in pen is not decided: [?].

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without the names of regions, cities, villages, seas, rivers, mountains and valleys, would be of use to no one, and could not be described or understood by anyone, however expert, so it is with this Selenography of ours as well. [Margin: Just as geography without names is intelligible to no one, so is this Selenography of ours.]

The ancient astronomers well understood this. In order to hand on to posterity their astronomical observations, which were to grow with time and the years, they gave names — according to their own capacity and the spirit of their age — both to the planets and to the general asterisms, and to individual stars as well, by which they might call each one distinctly, so that in later ages

they would be understood by students of the stars [Astrosophi], who could use the same nomenclature of the heavenly lights if they saw fit. For what, I ask, would the whole science of the stars be, if we could not properly separate and distinguish the stars themselves — something that comes about solely through names? All the observations of everyone, ancients and moderns alike, would be of benefit to no one, and the books that present them to us would seem riddles rather than descriptions and explanations. And what of this: that each and every thing contained within the compass of this world-machine, whether animate bodies or inanimate, was distinguished by its own name from the very beginning of created things, and that this was a concern of God himself, the Creator of the universe, and of Adam, the first-formed man, in the Hebrew tongue? The wise name-givers [Onomatothetae] of other nations followed them and, by a hidden prompting of God, devised other names for things in their own languages. Without that work this visible world would still be, in some part, a confused chaos — that is, imperceptible and incomprehensible to human beings.

Having weighed these and similar reasons on the balance of a careful mind, I at once judged it advisable to give names — of whatever kind, but distinct ones — to each and every region of the Moon. I readily confess that I have taken on an arduous task, since it is unheard of to distinguish the parts of so remote an ethereal body by definite names, and, so far as I know to date, no one has even attempted it, let alone carried it through successfully. Meanwhile, however, since the plan of our work required this of necessity (may it turn out well, with the most longed-for

benefit to astronomy and geography!), with God, best and greatest, as my sponsor, I undertook the venture, relying on the surest hope that no one of sound and good mind would misinterpret the effort of a well-meaning spirit.

For marking the places of the Moon with definite names, two methods presented themselves right at the outset. First, I thought it would not be unfitting to follow the example of the ancient astronomers, who gave the stars the names of men most excellent in virtue, who had deserved best of the world above all others (men whose memory they meant to make everlasting among posterity); for in this way those men were adorned with great honour, so that they have been famous from then on through every age — for example Hercules, Cassiopeia, Andromeda, Cepheus, Perseus with the head of Medusa, Bootes, etc., and others. [Margin: At first the author intended to give the names of eminent men to the lunar spots.]

In this way, I say, I too had proposed to bestow on all the territories of the Moon the names of eminent and most learned men of the present day, and above all of those who in our time have set about enlarging the mathematical sciences outstandingly and have most deservedly won the widest renown for it; so that their fame might be spread further still, and they themselves be placed in the heavens among the stars, to be attended with a happy remembrance for as long as the ether and the stars shall last. I had resolved to transfer to this true ethereal

Earth the Copernican Ocean, the Tychonic Ocean, the Keplerian Sea, the Lake of Galileo, the Marsh of Mästlin [Michael Mästlin], the Scheinerian Island, the Peninsula of Gassendi, the Mount of Mersenne, the Valley of Boulliau [Ismaël Boulliau], the Gulf of Wendelen [Govaert Wendelen], the Crügerian Promontory, the Eichstadian Strait [Lorenz Eichstaedt], the Desert of Linemann [Albert Linemann], and so on.

That would hardly have been unfitting, and I believe many agree with me on this point. But when I had thought over this whole business somewhat more carefully in my own mind, I seemed to see that it carried a certain danger, and that it could easily happen that, while I wished to win some favour with the nomenclature just described, I might perhaps stir up envy and enmity against myself. [Margin: Why the author changed his view.] For considering that there are many places on the globe of the Moon, some more prominent than others, and some also less notable, whether on account of their position or of their brightness, to all of which

nevertheless their own names had to be assigned, I understood that it could happen that I might perhaps give to one or another of these eminent men a place lower or less worthy, in the opinion either of the man himself or of others. From that, bile would be stirred up with no trouble at all, since some would suspect that this had been done because I thought less kindly and less honourably either of certain men's merits in the republic of letters, or of someone's nation or profession of religion, and that perhaps, prompted by some improper motive, I had preferred to this man or that people known to me and bound to me by the tie either of friendship or of faith. So I became entirely certain that I could not avoid giving offence in this way, however far my mind might be from any wish to offend. For this reason I preferred to let that way of naming the lunar spots go, and it seemed best to choose another, which is both entirely safe and, to confess the truth, better suited to our purpose and to the public good. [Margin: The author gave geographical names to the lunar spots.]

Beyond doubt, indeed, the Moon can rightly be called an Antichthon, a counter-Earth [Antichtona], since in many of its parts it is wholly similar to this Earth of ours (as will be pointed out, indeed taught, in its proper place) — namely in respect of oceans, islands, marshes, plains, mountains, valleys, and so on. Accordingly I judged it most expedient that only geographical names, and those already very widely known, should be given to the places of the Moon — provided (and this had to be investigated first) that the visible hemisphere of the Moon could be matched fittingly and aptly to some particular part of the terrestrial globe, as regards, that is, the arrangement of its places.

But when I had at once set my mind to the work of investigating this, and had thoroughly surveyed the whole of geography, I found, to my very great delight, that a certain part of the terrestrial globe, and the earthly places marked there, could be compared extremely well with the visible surface of the Moon and its regions, and that the names could therefore be carried over from there to here with no trouble and most conveniently. That part is the portion

of Europe, Asia and Africa which takes in the Mediterranean Sea, the Black Sea [Pontus Euxinus] and the Caspian Sea, together with all the remaining regions enclosed by them and adjacent to them, namely Italy, Greece, Anatolia [Natolia], Palestine, Persia, part of Sarmatia and of Tartary, Egypt, Mauritania, and so on. These places, that is, extend from the tenth degree up to the [Margin: A certain part of the terrestrial globe can be compared quite aptly with the visible hemisphere of the Moon.]

ninetieth degree of longitude, and from the twenty-fifth to the sixtieth degree of latitude.

Having thus compared the Moon's oceans and regions (if I may call them so) with these earthly ones, I marked them with common names, duly observing the following points in this naming. First, I paid particular attention to the arrangement of the places, so that the lunar spaces should not fail to agree excellently with the terrestrial ones. Second, I chose names of the first rank and best known to us, above all those that were in use among the ancients and are familiar to historians and to ourselves. For who does not know that the names of places on Earth vary a great deal in our age, and that this or that place is named in one way and another by different peoples? But where it was not possible to keep to what has just been said (as was sometimes impossible), I adopted, to serve our purpose, names that appealed to me and were not altogether unsuitable. [Margin: What names of places the author chose.]

Meanwhile I could never wonder enough that everything turned out so well, as I had at first never thought it would; and every student of the stars, once he has grasped this, will, I think, marvel at it and be astonished at it with me, and hardly lightly. Even so, there is no reason for anyone to persuade himself that the places of the Moon correspond exactly to our terrestrial ones, even in shape and in size and, finally, in every proportion (for whether it is so, or whether one could know that it is so, matters little for the present, as the wise readily gather); it is enough to have first detected some sort of arrangement of places and regions alike on both sides. I have used invented names scarcely once or twice, and only in a place where geographical nomenclature failed us. So few such names will be found, and only towards the north, since in the other parts truly geographical names were conveniently to hand.

Moreover, it was by no means enough simply to give names to the lunar tracts [oras]; it was also required that they be represented in such a way that anyone could easily commit them to memory and retain them well. To indicate the names found by numbers, set out separately outside the face of the Moon, did not seem expedient: for because of those many different numbers and the variety of names, scarcely anything could have been found, and so, because of the

Blank back of an engraved plate; it carries only a page numeral added by a later hand.

Diagram. Left half of a double-page engraved map of the visible face of the Moon, continued on the facing page. The lunar disc is bordered by two

graduated limbs numbered in tens, which cross each other on the western limb; at the top and along the outer scale at the foot the legend reads "Limbus Lunæ horizontalis in [♉?]" (the Moon's horizontal limb in [?]), and along the inner scale at the foot a further legend, read only at low magnification as "Limbus Luna horizontalis in" [?], ends with a sign of the form of Cancer [♋?]; the regions of the Moon carry names taken from the geography of the Mediterranean and the Near East. At top left two putti hold up a cloth bearing the title cartouche; at bottom left two more putti measure along a graduated rod with dividers, beside an armillary sphere and a book, and a block lettered "Scala Milliarium Germanicorum" (scale of German miles). The engraved figure letter at the foot reads "Fig. E [?]."[10]

Cartouche: *Selenographic Map, or a true delineation, made with the help of the telescope [tubus] in orthographic projection, of the seas, bays, islands, continents, promontories, lakes, marshes, mountains, plains and valleys existing on the visible hemisphere of the Moon. By Johannes Hevelius. In the year 164[?].*

Engraved names read on this half (as printed; names cut at the gutter continue on the facing page):

- North: REGIO H… (gutter); Montes Hyperborei; MARE H… (gutter); L.Ni [?]; L. Maior; Sinus Hÿperb; Atlas maior; Atlas minor; Paludes Orient; MAVRITANIA; [?] Appollinis.
- The western Mediterranean: MARE MEDITER-RA-NEVM; I. Maiorca; Cabra[?]; I. M[?]norca; I. Ophiuſa; I. Ebiſſus; S. Galli[?] (gutter); I. Erroris; M. Baroniſus; Alabaſtrinus M.; Pr. Lunæ; Pÿran… (gutter); I. Sardinia; I. Corſica; L. Marinus; I. Ficaria; S. Petro; I. Hiera; I. Calathe.
- The western limb: M. Pentadactylus; M. Porphyrites; MARE EOVM; M. Germanicianus; M. Audus; AFRICÆ PARS; Stagn. Miry; M. Thambes; I. Cr[?]; Cinna; Loca Paludoſa; LIBYÆ PARS; Pal. Mareotis; M. Climax; Fontes Amari; Acabe M.; M. Aiax; Fl. Nilus; ÆGYPTVS.
- Sicily and Italy: Coſyra[?]; I. Taracinia; I. Menÿx; S. Syrticus; SICILIA; Ætna M; M. Chalcidici; M. Neptunus; [?] Herculeus; Hybl[?]; Circa[?]um Pr.; S. Paſtanus; I. Vulcania; S. Hipponiates; MARE ADRI… (gutter); RO… (gutter); S. Tarantinus.
- The central and eastern Mediterranean: I. Æthuſa; I. Malta; I. Zachintus; C. de Form[?]; I. Po[?]tia; Syrticum Mare; Mare Ægyptiacum; L. Lea; M. Athos; Strophades; Peloponneſus; M. Micale; Melos I; Lemnos I; S. Strymonicus; Lesbos I; Rhodo I; M. Sipyl… (gutter); Creta; I. Carpathos; I. Cyprus; Mare Pamphilium.
- Egypt, Palestine and Arabia: Ca[?]ta Ara[?]es; M. Caſſius; S. Sirbonis; Caſſiotis Regio; M. Caſius; M. Nitria; Sinopium M.; PALÆSTINA; M. Porphir[?]; M. Horeb; Sinai M.; Deſert Zi[?]; Tabor M.; M. Liba[?];

[10] the capital is E or Q by its form and is not settled on this copy; the book's own list of figures places Figura Q between pp. 226 and 227, where this map stands, and Figura E between pp. 34 and 35.

Mortu um; M. Troicus; Fons Ta[?]nos; L. Meridionalis; M. Meridionalis; ARABIA; Haialon; Raphidim; M. Techiſa… (gutter).

- Limb figures (each beside its scale bar): along the first bar from the top 40, 50, 60, 70, 80, 90, 100; along the second 40, 50, 60, 70, 80, 9[?] (90 or 99); where the bars cross, 100 outside and 110 inside; then beside the outer bar 110, 120, 1[?]0 (130 or 150), 140, 150, 160, 170, 180, 190, 200, 210, and beside the inner bar 120, 1[?]0 (130 or 150), 140, 150, 160, 170, 180, 190, 200, 210.
- The putti's measuring rod, left to right: 10, 20, [?]0, [?]0, 50, [?], [?]0, 80, 90, 100 (the open figures lie under the putto's hand).

Right half of the double-page lunar map described on the preceding page, continued here. Two putti at top right hold a cloth bearing the key to the abbreviations:

Explanation of the letters: M. = mountain; I. = island; S. = bay [sinus]; L. = lake; P. = marsh [palus]; C. = cape; Pr. = promontory; Pal. = marshes; Fl. = river; Fret. or F. = strait.

At bottom right two more putti sight through a telescope, with dividers, a sector and an open book on the ground beside them; beneath them is a scale numbered 1, 2, 3 at its major divisions, with the smaller figures 15, 30, 60, 30, 60, [?]0, 60 along it, lettered "Digiti Ecliptici et eorūm Segmenta" (ecliptic digits and their parts). The limb legend at the top of this half reads "Limbus Lunæ horizontalis in ♋" (the Moon's horizontal limb in Cancer), with the band figures 30, 20, 10 set between its words; the legend at the foot reads the same, its sign not re-read [♋?].

Engraved names read on this half (as printed):

- North: ŸPERBORIA and ŸPERBOREVM (apparently completing the names cut at the gutter on the left half); ARE… (gutter); Sarmatici. M.; Bontas; Scopuli Hÿperb.; N[?]ger min.; M. Serrorum; M. Au… [?]eus; Alpes (twice); M. Carpathes; M. Peuce; M. Ambenus; M. Macrocemni; P. Amadoca; L. Supe[?]; L. Hÿper[?]; [?]ferior; Pr. Leucopetra; M. Æmus; Pr. Hippolai; MOESIA; L. Borÿſthenes; S. Cercinitis; M. Bodinus; Paludes. Hÿperb.; SARMATIA EVROPEA PARS; Amadoci. Montes; M. Alanus; M. Riphæi (twice; on one a band figure crosses the æ); M. Athriſti; M. Li[?]ſtinus.
- The Black Sea: Pal. Superiores; S. Salmÿdeſſus; S. Sagaricus; PONTVS EVXINVS; Pal. Inferiores; I. Cÿanea; Apollonia; Pr. Archeruſia; Bÿzantium; Archeruſia P.; [?] Ad. Helleſpontum; I. Beſbicus; PROPONTIS; Apolloni… a. Mi[?]; Erich[?] Scopuli.; Aconitus Collis; M. Pangæus; …ATICVM; M. Trapezus; TAVRICA; M. Beroſus; CHERSONESVS; Palus Bÿces; L. Corocondametis (set as Coroconda / me / tis); M. Cimmerius; Corax M.; PALVS MOEOTIS; Pr. Agarum; Alopecia I; S. Caucaſius; I. Aea; Pr. Herculeum; SARMATIA ASIATICÆ P; L. Maior; L. Minor; Pal. Ama[?]; I. Cilicum; I. Arrhentias; I. Philÿra; S. Phaſianus; Pr. Chadiſia; Pr. Heracleum; S. Athenienſis.

- Asia Minor and the Caspian: M. Amanus; M. Olÿmpus; Herculis; M. Horminius; ASIA MINOR; MARE CASPIVM; M. Tmolus; M. Didÿmus; Lipulus; Fret. Ponticum; Moſchus; S. Extremus Ponti; COLCHIS; M. Tancon; S. Inferior; I. Minor; I. Maior; Hippoci Montes; Paludes; PARS; Petra Sog[?]; Neroſus. M.; Caucaſus; Areeſa. P.
- The south-east: M. Taurus; M. Armenia; Antitaurus. (and a second Anti-taurus below it); PERSIA; M. Coibacarani; M. Paro[?]pam[?]; SCYTHIÆ; Seir; M. Dalan… guer [?]; Deſertum Mingui.
- Further names read on the re-read (those marked [?] are probable or have an open letter): Taurus (a second label); M. Myſi…; M. Cora…; S. Sa[?]… chus; Occi… (two vertical labels at the eastern rim); Catena Mund. [?]; S. Peronticus [?]; [?]. Macra; Pr. Arichis [?]; M. Cadmus [?]; Celenorum [?]; mulus [?]; M. Cyd[?]ſſes; Anti Libanus [?]; [?]ortis; Thoſpiti[?]; P. (on two islets); Lÿchnitis [?]; Mantian[?]; [?]ferior; M. Sog… di… ani; M… Cal… chas… tan (spread among mountains); …ndam (gutter); …ninus; [?]ANIA.
- Limb figures. Outer band: 30, 20, 10 (set between the words of the top legend), 360, 350, 340, 330, 320, 310, 300, [?]90, 280, 270, 270, 2[?]0. Inner band: 30, 20, 10, 300 (as engraved, where the run would have 360), [?]50, 340, 3[?]0, 320, 310, 300, 290, 280, 260 [?], 250 [?]. Southern and south-western band: 240, 250 [?], 230, 240, 2[?]0, 230, 220. Ring membership near the crossing at 270–280 is by position only.

Blank back of the plate; the map shows through in mirror image.

confusion, this work would have been extremely tiresome and tedious. I therefore found another method: to construct a Selenographic Map drawn orthographically and geographically. By its help I foresaw that this whole undertaking would turn out well, and that students of selenography would easily come to know all the names used here, and commit them to memory, with much greater pleasure and with less labour; and — what matters most — that it would greatly serve my purpose from then on, and would be a true means of rightly illustrating and understanding this whole selenography. [Margin: The author has represented the names of the places of the Moon in a selenographic map drawn geographically.]

I constructed this Selenographic Map in the same way as maps and geographical charts usually are, and placed it before the public eye, that is, with two points necessary for it carefully observed. First, that the regions and islands, with all their boundaries, angles and so on, should be drawn most accurately according to their true measure and to the proportion of both longitude and latitude. Second, care was also taken that the seas, and likewise the lakes, rivers and marshes, with the bays, promontories, crags and so on, should be sketched with careful work, keeping their due proportion. On it I also marked off the shores of the oceans themselves with definite lines, in the manner customary among geographers, and likewise, as is usual, the marshes, the mountains and the valleys: so that not even beginners should fail to tell the continents, at first

glance, from the marshes, pools and seas. For from the earlier ichnographic map [Tabulâ Ichnographicâ], as also from the other phases, not everything is perceived so conveniently, nor so quickly. The lunar mountains, lesser and greater as they really are, are likewise distinguished on this map according to their height, so that the difference can be detected without difficulty. How I was able to know so accurately the position of the places and the differences between the mountains will be told below. Further, I have also added to this map the collected names of all the places, so that both the positions of the places and the names themselves should be set before the eyes together. [Margin: The selenographic map is constructed like a geographical one.]

By this route, as we have said, those who cultivate astronomy will acquire a knowledge of all these things without difficulty, since the names introduced here in order are very familiar not only to historians but also to poets, indeed to almost all who are learned in letters. And so that

no discrepancy between the ancient and the present-day names should trouble anyone, both are given together.

The names expressed on the Selenographic Map we have marked in capital letters and the rest in smaller ones — for clearer distinction, of course — and we have added several more besides, which we thought would conduce to a better understanding. Finally, so that they could be found more quickly, we have arranged all the names in alphabetical order. As for the Selenographic Map itself, I judge that it will be very conducive and useful for all observations, both for making observations properly and for understanding them rightly; and this will be shown more fully below, in its own time and place.

Tabulæ Selenographicæ nomina, eaq; propria Marium, Sinuum, Inſularum, Continentium, Promontoriorum, Cherſoneſorum, Lacuum, Paludum, Fluminum, Planitierum, Montium, & Vallium.

The names of the Selenographic Map: the proper names of the seas, bays, islands, continents, promontories, peninsulas [Cherſoneſorum], lakes, marshes, rivers, plains, mountains and valleys.

A

- **Abarim Mons**: called Nebo and Phasga; on it Moses died.
- **Acabe**: a mountain of Egypt, on the Arabian Gulf.
- **Aconitus**: a hill, where the Archerusia cave also is.
- **Adriaticum Mare**: today the Golfo di Venetia; Vitruvius calls it the Gallicae Paludes. The innermost recess of the Adriatic Sea, in which Venice lies, is today the Lagume di Venetia.
- **Aëa**: an island, today, unless I am mistaken, Satabella.
- **Ægyptus**: a most celebrated region of Africa, once Æria, Ætia, Ogygia, Hophæstia; also called Chemia, on the testimony of Herodotus. By the

Hebrews it is called Chus, by the Turks Elchebitz, and in the Egyptian language Cam.

- **Ægyptiacum Mare**: the Egyptian Sea.
- **Africæ Pars**: part of Africa.
- **Æmus Mons**, or Hæmus: a mountain of Thrace; the Italians call it Catena Mundi and Monte Argentario, the Turks Balkan.
- **Ærii Montes**: of Sicily, and so called in former times as well.
- **Ætna Mons**: of Sicily; the Pillar of Heaven [Cæleſtis Columna] in Pindar; Mount Tiphæus in Silius Italicus; today Mongibello or Monte Gibello; formerly called Inesia, as Volaterranus [Raffaele Maffei] records.
- **Æthusa**: an island not far from Sicily. Others call it Ægusa, Limoza, Ægates.
- **Ajax**: a mountain of Egypt.
- **Agarum**: a promontory of European Sarmatia.
- **Alabastrinus Mons**: of Africa.
- **Alani**, or **Roxolani Montes**: near the river Tanais and the Maeotic Marsh.
- **Alopecia**: an island of the Maeotic Marsh, which is also named Tanais, and likewise Calarus and Alopece. Socrates came from here, on the testimony of Laertius [Diogenes Laertius] in his life and of Plato in the *Gorgias*; some also call it the Isle de Renards.
- **Alaunus Mons.**
- **Alpes**: very long tracts of mountains, which separate Italy from Germany and France like a natural wall. Strabo records that they were once called Albia and Alpionia. They are also distinguished by different names by various authors: see Ortel. [Abraham Ortelius].
- **Amaræ Paludes.**
- **Amari fontes**: of Egypt.
- **Amadoca**: a marsh.
- **Amanus Mons**: otherwise Cedrenus, or Monte nigro.
- **Ambenus Mons**: near the mouths of the Ister in European Sarmatia; it is also called Ambolus and Embolus.
- **Anemusa**: an island lying between Leopadusa and Æthusa; these are also called the Pelagian Islands [Pelagiæ … Inſulę], and on the map of Africa they are named Tariciniae.
- **Annæ Mons**: of Arabia Deserta.
- **Antilibanus**: a mountain.
- **Antitaurus**: a mountain.
- **Apenninus Mons**: in Italy it is given different names according to the variety of places.
- **Apollinis Promontorium**: in Mauretania Caesariensis; today Cabo de Tenes, or Cabo de tres forcas.
- **Apollonia**: an island, also called Thynias.
- **Apollonia minor**: an island of the Black Sea [Ponti Euxini].

- **Arabia**: today Aden; some call it Aiman, but the Saracens Mamotta.
- **Arabiæ Paludes.**
- **Archerusia Palus**, or Anthemoisis: on the Black Sea.
- **Archerusia Promontorium**: by the Island of Apollo in the Black Sea.
- **Areesa Palus**, or Arsena, Arethusa: in Greater Armenia.
- **Argentarius Mons**: a peninsula or promontory of Tuscany; today Monte Argentaro, where the Portus Herculis once stood.
- **Arietis frons**, or promontory: formerly Brixaba or Acroma, a promontory of the Tauric Chersonese.
- **Armeniæ Montes**, or the Gordiaei.
- **Arrhentias**: an island near the Cappadocian Sea [Pontum Cappadocicum].
- **Asiæ Pars**: called Semia by the sacred writers, but Siana by the peoples of Asia.
- **Atheniensis Sinus**: named after the Athens of Cappadocia, not of Greece; it is otherwise called Themis and Cyrium, today Cacari.
- **Athos Mons**: of Greece; today Monte Sancto; to the Turks, Monastir.
- **Atlas minor**: a mountain in Africa.
- **Atlas major**: likewise a mountain in Africa.
- **Audus**: a mountain of Africa.
- **Aureus Mons**: in Moesia; there are also others of this name in various regions.

B

- **Baronisus**: a mountain of the Kingdom of Fez and of Morocco in Africa.
- **Besbicus**: an island of the Propontis; today it is called Calomio or Calolino.
- **Berosus**: a mountain; on it are three springs that are deadly, without pain and without remedy. Pliny.
- **Bodinus**: a mountain.
- **Bontas**, a mountain, or Tabas: situated near the Montes Serrorum.
- **Borysthenes**, a lake: near the Black Sea, into which the river Borysthenes discharges itself.
- **Byces**, a marsh: elsewhere, indeed, it is part of the Maeotic Marsh, but here it is part of the Black Sea; for since no other bay presented itself in geography, it was decided to keep this name.
- **Byzantium**: today Constantinople.

C

- **Cadmus**: a mountain of Asia.
- **Calabraria**: islands of the Balearic Sea; today Montcolibre.
- **Calathe**: an island of the African Sea, not far from Sardinia.
- **Calchistan**: a mountain of Persia.
- **Capraria**: an island; today Cabrao.
- **Carpathes**: a mountain of European Sarmatia, in Ptolemy. The Germans call it Den Münch, Vatter, Wurtzgarten and Schneberg: see Ortelius.

- **Carpathos**: an island, formerly also called Crapathus, Porphyris and Tetrapolis; today Scarpanta.
- **Caput de Tornese**: of the Peloponnese.
- **Carcinites**, a bay, which is also Tamyraces; today the Golfo di Nigropoli.
- **Cassiotis**, a region: in Egypt or Syria.
- **Casius**: a mountain of Egypt, today Larissa, on which is the tomb of Pompey the Great.
- **Caspium Mare**, or Hyrcanum: it is called Albanicum and Tartaricum; today Abachu, Sala, Cunsar, etc.
- **Catarractes**: a mountain of Egypt, not far from the Nile.
- **Caucasius Sinus**: of the Black Sea.
- **Caucasus**, or **Caucasii Montes**: part of Mount Taurus, lying between the Black Sea and the Caspian Sea; otherwise the Marpesia Cautes; today Cochias.
- **Celenorum tumulus**: mountains of Pamphylia.
- **Cercinna**: an island of the African Sea; today it is called Gamelaria and Querquenes.
- **Chadisia**, a promontory: otherwise Phadisana.
- **Chalcidici Montes**: today S. Riti.
- **Cilicum**: an island of the Black Sea.
- **Cimmerius**, a mountain: in the Tauric Chersonese.
- **Cimmeriae Paludes.**
- **Cimaeus**: a mountain of Asia.
- **Circaeum**, a promontory: today Monte Circello.
- **Cirna**: a mountain of Africa.
- **Climax**: a mountain of Egypt.
- **Coibacarani**: mountains in Persia.
- **Colchis.**
- **Corax**: a mountain of Asiatic Sarmatia.
- **Corocondametis Lacus**: on the Black Sea.
- **Corsica**: an island, which is also Cyrnus, Corsis and Cerneatis, situated in the neighbourhood of Sardinia.
- **Cosyra**: an island, or Cossura, otherwise Pantalaria, not far from Sicily and the Promontory of Mercury.
- **Cratas**: a mountain.
- **Crathis**, or **Chelidoreus**: a mountain of the Peloponnese; formerly, unless I am mistaken, Stymphalus.
- **Cragus**: a mountain of Cilicia.
- **Creta**: an island, or Candia; formerly called Aeria, Curetis, Macaros and Macaronesos.
- **Creticum Mare.**
- **Cydises**, a mountain: near Armenia.
- **Cyprus**: an island of the Mediterranean Sea, which has been called by various names: Aca-

mantis, Cerastis, Aspelia, Amathus, Macaria, Cryptus, Colinia, Sphecia, Mejonis, Aerosa, Paphus, Chetima, Citica, etc.

- **Cyanea Europeja**: an island lying next to the Thracian Bosporus.

D

- **Delanguer**, a mountain, formerly Imaus: it rises from the roots of Taurus; by Ptolemy they are called the Chemantini Montes.
- **Didymae**: islands of the Mediterranean Sea.
- **Didymus**: a mountain of Asia Minor; elsewhere very many mountains of this name are found.

E

- **Ebissus**: today Yvica, an island of the Balearic Sea.
- **Echinades**: these are islands of the Ionian Sea; in our time they are called Cozzulari.
- **Eos**: a mountain of Egypt.
- **Eoum Mare**, or the Eastern Sea [Orientale].
- **Erichtini Scopuli**: in the Black Sea.
- **Erroris Insula**, which is also Albusama: of the Mediterranean Sea; today it is called Alboran.
- **Eryx Mons**, or **Montes Erycini**: today Trapani and Monte S. Iuliano, in Sicily.
- **Evila**: a desert in Palestine.

F

- **Ficaria Insula**: today Serpentaria, near Sardinia.
- **Fontes amari**: on the Nile in Egypt.
- **Fretum Ponticum.**
- **Fortis**, a mountain.

G

- **Gallicus Sinus**: the name given to that part of the Mediterranean Sea where the Rhône pours itself into it; elsewhere it is also sometimes named Angulus Gallicus and Salsus, near the Aphrodisium Promontorium.
- **Germanicianus mons**, otherwise Iovis: in Africa.

H

- **Hajalon Vallis**: in Palestine, or, as others name it, the Valley of the Moon [Vallis Lunę].
- **Herculeus Lacus**: situated in Sicily near Etna; it was four stadia in circumference, in the territory of Leontini. Diodorus Siculus.
- **Herculis Mons**: next to the Promontorium Heracleum.
- **Hereus**: a mountain of Sicily, otherwise Artisino and Tauis.
- **Herculeum Promontorium**: on the Maeotic Marsh.
- **Heracleum**: a promontory of the Black Sea.
- **Hermo Mons**, and **Galaad**: of Palestine.
- **Hiera**: an island next to Sicily, and Hieronesos, or named Maritima; today Maretamo, not far from the Lylibaeum Promontory, where other islands are also found.

- **Hippoci Montes**: today Mazarisci, in Asia, near Tartary.
- **Hippolai Promontorium**: in European Scythia, on the Borysthenes.
- **Hipponiates Sinus**: by others called Vibonensis, Terinaeus, Napetinus, Bruttius, Lameticus; today the Golfo di Taranto.
- **Hor**: a mountain of Palestine.
- **Horminius Mons**, or Ormenius: in Asia, on the Pontus.
- **Horeb**: a mountain of Palestine.
- **Hiblaei Montes**: of Sicily.
- **Hyperboreum Mare.**
- **Hyperboreae Paludes.**
- **Hyperborei Montes.**
- **Hyperboreus Lacus Superior.**
- **Hyperboreus Lacus Inferior.**
- **Hyperborei Scopuli.**
- **Hyperborea Regio.**

I

- **Ida**: a mountain of Asia, in Lesser Mysia.
- **Insula Orientalior**: of the Carpathian, or Libyan, Sea.
- **Insula Occidentalior**: in the same sea.
- **Insula**: by the Promontorium Arietis, in the Black Sea.
- **Insula Major**: of the Caspian Sea.
- **Insula Minor**: of the Caspian Sea.
- **Italia**: it was once called Vitalia, Apennina, Argessa, Ausonia, Camesena, Hesperia, Janicula, Oenotria, Saleombrona, Saturnia, Tourina and Vitullia.

L

- **Lacus major occidentalis**: on the Maeotic Marsh, or, by a particular name, Odojum, Lacus, and Iwanow.
- **Lacus minor occidentalis**: by a particular name, Lacus Ploto.
- **Lacus Meridionalis.**
- **Lacus Niger Major.**
- **Lacus Niger minor.**
- **Lathmus**: a mountain of Asia Minor.
- **Lea**: an island by the shore of Barbary.
- **Lemnos**: an island of the Aegean Sea; today it is called Stalimene.
- **Lesbos**: an island of the Aegean Sea; formerly also called Hemerte, Lasia, Aegira, Pelasga, Aethiope, Macaria, Mitylena and Mytaneda; today Metellino.
- **Letoa**: an island of the Mediterranean Sea, near Crete; by others it is also called Christiana.
- **Leucopetra Promontorium**: today Capo de Larme.
- **Libanus**: a mountain of Syria.
- **Ligustinus**: a mountain of Italy.
- **Lion**: a mountain in Arabia Deserta.

- **Lipulus Mons.**
- **Loca Paludosa**: in the island of Cercinna, in the middle of which a notable hill is seen.
- **Lunae Promontorium**: in Tuscany, not far from the Gallicus Sinus.
- **Lybicum Mare**, or rather Aegyptiacum.
- **Lychnitis**: a marsh of Greater Armenia; today Exsechia.
- **Lybiae Pars**: of Africa, which they formerly also named Olympia, Oceania, Hesperia, Cephenia.

M

- **Macra Insula**, which is also Achillis, and likewise Leuce: it lies in the Carcinites bay.
- **Macrocemni Montes**: in European Sarmatia.
- **Malta**, or Melita: an island.
- **Majorica**: an island of the Balearic Sea.
- **Mampsarus**: a mountain of Africa.
- **Mantiana Palus**: today it is called Geluchalat or Actamar.
- **Marinus Lacus**: in Tuscany, by the Herculis Portus; today Lago d'Orbitello.
- **Masicytus**: a mountain of Asia Minor.
- **Mauritania**: a region of Africa; by the Hebrews it is called Phut, today the Regnum Tremissinum. By the Spanish, French and Italians it is called Barbaria.
- **Mediterraneum Mare**: by the Italians and Spanish it is called Mare Levanto, by the Turks Actenitz, that is, White, and by the Arabs Bohar Rumi; it is also called elsewhere Mare magnum (the Great Sea), Mare internum (the Inner Sea) and Mare intestinum (the Inland Sea).
- **Melos Insula**: called by various names in former times; see Ortelius. Pliny writes that of all the islands in Greece it was the roundest.
- **Menyx Insula**, which is also called Lotophagitis and Cyra: an island of the African Sea, not far from the Syrtes.
- **Mercurii Promontorium**: of the Mediterranean Sea, by Africa.
- **Mesogys**: a mountain of Lydia.
- **Micale**: a mountain of Ionia.
- **Mimas**: a mountain of Ionia.
- **Mingui**: a desert, or Carmania, in Asia.
- **Minorica**: an island of the Balearic Sea.
- **Miris**, or Moeris: a lake, in which is the tomb of King Maeris.
- **Mons Meridionalis.**
- **Montana Pharan**: in Palestine.
- **Montana Seir**: in Palestine; today Sardinay.
- **Montuniates**: a mountain in Tuscany.
- **Mortuum Mare**: in Palestine.
- **Myconius**: a mountain of Sicily, near Messina.

- **Moesia**: a region of Europe; some call it Servia, others Bosna and Moldavia.
- **Mysius**: a mountain of Asia, formerly called Saturni Collis; by the Turks, however, it is today called Geschisdage.

N

- **Neptunus Mons**: today Monte de Namari, not far from Messina, in Sicily, by the Fretum Mamortinum.
- **Nerossus**: a mountain of Tartary.
- **Nilus**, or the river Triton.
- **Nitriae Mons**: of Egypt.

O

- **Olympus**: a mountain of Asia, or Olympus Mysicus; today it is called Kischisdag. Elsewhere there were twelve more mountains named Olympus, namely in Cyprus, Macedonia, the Peloponnese and Lycia.
- **Ophiusa**: today Fomentera; an island of the Balearic Sea.

P

- **Paludes**: around the Dead Sea.
- **Paludes Palaestinae.**
- **Paludes Superiores**: of the Black Sea.
- **Paludes Inferiores**: of the Pontus.
- **Palus Maraeotis**: in Egypt.
- **Palus Maeotis**, or Maeotica: today Mar dello Sabacche, Mar della Tana and Mar Bianco.
- **Pamphylium Mare**, or Phaselicum.
- **Pangaeus Mons.**
- **Paestanus Sinus**, or Posidoniates: today the Golfo Agropolitano, or Golfo di Salerno, of the Mediterranean Sea.
- **Paropamisus Mons**: part of Taurus; there it rises to a most outstanding height. By Aristotle it is called Parnassus, but today Pamer.
- **Parthenius**: a mountain of the Peloponnese.
- **Peloponnesus**: today the Morea peninsula; formerly named Apia, Pelasgia, Argos, Pelopia, Inachia and Aegialia.
- **Pentadactylus**: a mountain of Egypt, by the Red Sea.
- **Peronticus**: a bay of the Black Sea; today Cabo de Manco.
- **Persia**: a region of Asia; today it is called Farsi, Azamia and Curasan.
- **S. Petro Insula**: it lies by Sardinia; formerly called Herculis Insula.
- **Petra Pyramidalis**, or Pyramis, or Mons Faronianus: in Tuscany.
- **Petra Sogdiana**: by the Hyrcanian Sea.
- **Peuce**: a mountain in European Sarmatia.
- **Phasianus**: a bay of the Pontus.
- **Pherme**: a mountain of Egypt.
- **Philyra**: an island of the Black Sea, near the Sinus Phasianus.
- **Phoenix**: a mountain opposite the island of Rhodes.
- **Pontia**: an island of the Mediterranean Sea.

- **Pontus Euxinus**: it has taken various names from various authors: Axenus, Amazonius, Scythicus, Pontus Tauricus, Mare Cimmerium, Colchicum, Caucaseum, Mare Ponticum, Phasianum, Sarmaticum, Mare Boreale, Pontus nigrus; today Mar de Marmora, Mar Majore and Caradenis, and Maurothalassa among the Turks.
- **Porphyrites**: a mountain, red as if with minium, as Agatarchides reports; and here on the Moon it is of almost the same colour.
- **Promontorium freti Pontici.**
- **Propontis**: a bay of the sea between the Hellespont and the Black Sea; otherwise the Bebrycium Mare, Thracium; today Mar de Marmora.
- **Prophetarum Mons**: of Palestine.

R

- **Raphidim**: a desert in Palestine.
- **Rhodus**: an island, formerly called Macaronesos, and given various other names as well.
- **Riphaei Montes.**
- **Rupes**: in the Athenian bay.

S

- **Sacer**: a mountain of Egypt.
- **Sagaricus**: a bay of European Sarmatia.
- **Salmydessus Sinus**: today Philia Promontorium.
- **Sanctus Mons**: by the Maeotic Marsh.
- **Sardinia Insula**, which is also called Sandaliotis and Ichnusa.
- **Sarmatiae Europaeae Pars.**
- **Sarmatici Montes**: in European Sarmatia; today Scepusienses.
- **Sarmatiae Asiaticae Pars.**
- **Scithiae Pars**: today Tartary.
- **Sepher Mons**: of Palestine; but another of this name, the greatest in the whole world, is also found in India; and here on the Moon it stretches out very far.
- **Serrorum Mons**: of European Sarmatia.
- **Sicilia**: an island, which is also Sicania, Trinacria and Triquetra, on the testimony of Pliny.
- **Sinai Mons**: today Catharinae; by the Turks Turla and Gebel Thor; in Arabia Petraea.
- **Sinopium Mons**: of Egypt; otherwise Memphidis Mons.
- **Sinus Orientalis**: of the Hyperborean Sea.
- **Sinus inferior**: of the Caspian Sea, in which a notable rock is seen; elsewhere this bay is called Scythicus.
- **Sinus Extremus**: of the Black Sea.
- **Sinus ad Bosphorum Thracium**: of the Propontis.
- **Sinus ad Hellespontum**: of the Propontis.
- **Sipylus**: a mountain of Asia Minor; elsewhere very many mountains of this name are found.

- **Sirbonidis Eruptio**, or fretum Sirbonicum.
- **Sirbonis Sinus**: in Africa, not far from the Nile; or Palus Sirbonis. In Holy Scripture it is the Torrent of Egypt; today Golfo di damiata.
- **Sogdiani Montes**: the boundary between the regions of Media and Assyria; today Cabusco.
- **Strobilus**: a mountain, part of the Caucasus.
- **Strophades**: two islands of the Ionian Sea.
- **Strymonicus Sinus**: today the Golfo de Contessa, in the Aegean Sea, or Archipelago.
- **Syrticus Sinus minor**, which is also Lotophagitis: by Africa.
- **Syrticum Mare**: these are shallow places; in it there are very many rocks, namely the shoals of the sea [Maris Brevia], and sandy places; today Secche de Barbaria, or Braxas de Barbaria.

T

- **Tabor Mons**: of Palestine.
- **Taigetus**: a mountain of the Peloponnese.
- **Tancon**: a mountain, near the Caspian Sea.
- **Tarantinus Sinus**: of the Mediterranean Sea; today the Golfo di Taranto.
- **Taurus**: a mountain of Asia, the greatest in the whole world, and here on the Moon the greatest of all.
- **Taurica Chersonnesus**, which is also Chersonnesus Pontica, Taunaim, Alopecia, Chersena. In our age it is called Perokopska, Gesara, Gazaria or Cazaria.
- **Taraciniae Insulae.**
- **Techisandam Mons**: of Persia.
- **Thambes**: a mountain situated in Africa.
- **Tenarium Promontorium**: today Capo Matapan, in the Peloponnese.
- **Thospitis**: a lake.
- **Tmolus**: a mountain, otherwise Timolus, situated in Phrygia.
- **Trapezus Mons**: in the Tauric Chersonese; otherwise Lustra; today Trebizonda; by the Turks it is called Tarabossan.
- **Trasimenus**: a lake in Italy; today Lago de Perugia.
- **Troicus**: a mountain, the source of the Pyramids of Egypt.

V

- **Vulcania Insula**: otherwise Vulcani templum; today Vulcano, not far from the island of Lipara. It lies in the Mediterranean Sea, to the right of the island of Sicily, near Italy.
- **Uxii Montes**: in Greater Armenia, where the Tigris takes its source.

Z

- **Zacynthus Insula**: near the Peloponnese; at one time it was called Cassiopa and Hierusalem; today Zante.

Here you have the names of all the places on the Moon, which are likewise contained in the Selenographic Map. Now, in addition, I shall speak of the varied position, variation and properties of the places already mentioned, and

also, somewhat more fully, of our Selenographic Map, of the full moon and of all the remaining phases. But so that everything may run more smoothly, as I would wish, and the whole be made much clearer to readers, I have resolved first to treat fully of the motion of libration of the Moon's disc. (This motion was entirely unknown to the ancients, and to this very day has been explored by no one, much less demonstrated openly and clearly by trustworthy observations.) It is a matter of such a kind that knowledge of it is most re-

[Margin: The motion of libration of the disc is explained by the author; it was wholly unknown to the ancients, and has not yet been explored by the moderns either.]

quired both for Selenography and for the correct understanding of all lunar matters and phases. Indeed, without its help not even the least phenomena of the Moon can be properly explained and demonstrated.

In the preceding chapter, it is true, I spoke at sufficient length, as the matter required, of the varied motion of the Moon to which the Moon is subject; but of this motion of libration no mention at all was made, since the occasion did not allow it there. I did, however, mention a certain motion of libration: namely, how the centre of the first epicycle, on the eccentric, librates to and fro on the lesser diameter of the epicycle, though with a motion analogous to circular motion. That motion, however, is not the one I have now resolved to speak of, much less some motion of longitude and latitude — except that this motion of libration, mentioned above, does in fact arise from the Moon's proper motion and accommodates itself to it in every respect, as will be demonstrated below most clearly.

[Margin: What the difference is between the Moon's proper motion and its libratory motion.]

Between this new libratory motion and all the other motions that belong to the Moon there is, from the very outset, a great difference. The motion of longitude, which proceeds according to the order of the signs, and likewise the motion of latitude, are detected and recognized with complete certainty with respect to other stars; and from this we rightly judge that some such motion exists about the Moon, since the Moon is seen now in the neighbourhood of this fixed star, now near another. Thus, as I have said sufficiently, the Moon's progress both in longitude and in latitude can be plainly inferred from its varying position relative to the fixed stars.

[Margin: Because of the motion of libration the Moon is not moved from its place.]

As for the motion of libration of the disc, however, we can by no means recognize or investigate it from a varying position with respect to the fixed stars, but solely from the body of the Moon itself. Nor is it a motion that moves continuously from a certain place to another place and out of its true position (which is otherwise common to all motions). For if the Moon did not share in those motions already mentioned, the motion of libration would certainly produce no change of place about it, since this motion takes place about its

own axes and poles, like the motion of an artificial celestial or terrestrial globe, which is turned right round in a circle although it cannot be moved from its place at all.

[Margin: Libration takes place about its own poles.]

Yet by reason

of this motion any point placed under the meridian is moved away from it and another is brought up to it, as is easily understood. And so it is with the Moon's motion of libration. For although the Moon is not, on that account, displaced from its position at all, the visible centre of the lunar disc is nevertheless carried, on this basis, either forwards or backwards, upwards or downwards; so that its centre must necessarily be taken to lie now near this spot, now near another.

[Margin: Towards which quarter of the sky the lunar poles face.]

These poles, about which this revolving takes place, are to be seen on the preceding Selenographic Map at the very intersections of those two limbs: one on the left, roughly towards the east-north-east [Hellespontium], near Mons Pentadactylus; the other on the right, towards the south-west [Africum], near Petra Sogdiana. The motion of libration is thus carried from the north-north-west [Circio] to the south-east [Euroaustrum], and from there back again to the south-south-west [Austroafricum].

[Margin: The poles move in part.]

This libration, however, is not always equal, because the poles are by no means fixed but are in part movable. Yet there is no reason, kind reader, for you to persuade yourself that by means of this libration the Moon is turned completely round in a circle, like an artificial globe, which is carried round on every side. Rather, the Moon is turned round only in part, with respect to us, and turns towards us, for us to see, only a certain small portion of its hidden hemisphere: now, that is, the upper part, lying towards the north-west, around the Lacus Hyperborei; now the lower part, towards the south-west, around the Lacus Meridionalis and the Mons Meridionalis.

[Margin: The Moon is not turned completely round, but only in part.]

The limits of greatest and least libration are shown by these two limbs of the Moon, and the space lying between them is the greatest variation of libration. How great it really is, and what else is to be noted here, will be stated a little later.

For first, so as not to keep the lover of the stars [Astrophilum] who is eager for this knowledge waiting any longer, I shall show from where and how this motion derives its origin. This I can now share with everyone without any trouble, and in such a way that anyone can grasp without difficulty that this motion has its origin from no other source than the one I shall derive it from. I shall do this all the more willingly because I am well aware that scarcely anyone

will have grasped it rightly, when I call to mind how much labour and trouble the matter cost me, above all as I investigated the genuine limits and the true period of the libration — until, by means of exceedingly frequent and

long-continued observations, I was able to settle something certain on this matter for myself.

[Margin: The motion of libration arises from the Moon's proper motion.]

This motion of libration arises chiefly from a threefold motion. First, from the motion of longitude, which advances along the course of the ecliptic through the twelve celestial signs. Second, from the motion of latitude, from the position of the nodes and limits, and in this way: just as the Moon, by its own proper motion in longitude, is carried daily — indeed at every moment — in the order of the signs, so too, by reason of this motion, it turns a certain part towards us, forwards, that is, from the north-west to the south-east, while it stays in the ascending signs, namely Capricorn, Aquarius, Pisces, Aries, Taurus and Gemini; and backwards again, from the south-east towards the north-west, in the descending signs, Cancer, Leo, Virgo, Libra, Scorpio and Sagittarius.

[Margin: By reason of libration the Moon is widened on one side and compressed on the other.]

In this way, therefore, when the Moon is in Capricorn, the innermost limb — the one that passes through the Lacus Hyperborei and the Montes Amadoci, between Palus Mæotis and the Lacus occidentalis minor (if one attends to the upper part of the preceding and the following figure) — marks the true and genuine periphery of the visible hemisphere. At that time a very thin interval is to be seen between the very edge of the Moon and Palus Mæotis; on the opposite side, by contrast, between the periphery and Palus Mareotis [Paludem Maræotidem], a very broad space is seen, as is evident from the figure of the full moon itself. In the upper part, towards the north [Aquilonem], above the Mare Hyperboreum, that interval up to the periphery is very much narrowed; in the lower part, on the contrary, towards the south, so much the larger a part of the Moon is seen. But when the Moon stands at the beginning of Cancer, then the outermost horizontal limb of the Moon (if you consider, that is, the upper part of the Moon) represents the true and native visible hemisphere of the Moon, so that its face presents an entirely different aspect: for the space between Palus Mæotis and the periphery at that time

is very wide, so that two rather long spots can be made out distinctly. On the opposite side, again, between Palus Mareotis and the Moon's margin, it is narrowed all the more. The upper part of the Moon, however, is at that time at its largest, so that you cannot fail to see clearly not only the Lacus Hyperborei but also Palus Amadoca [paludem Amadocam], which stand a fair distance from the limb (although, when the Moon is in Capricorn, very little of these lakes appears); around the south [Austrum], by contrast, no small part of the Moon is hidden again. That this is so and not otherwise will be shown amply in what follows, both from my own observations and from those of the most distinguished men Gassendi and Boulliau [Bullialdi] recorded in the recently published *Astronomia Philolaica*; to these I refer the reader.

[Margin: The period of the libration is completed each month.]

Just as the Moon by its proper motion runs through the twelve celestial signs each month, so too this motion of libration of the disc is completed in the space of a month. For about fourteen days, while the Moon lingers in the descending signs, the disc librates backwards against the order of the signs, from the south towards the north-west [Corum] and the upper part; again, for about fourteen days, while the Moon remains in the ascending signs, it is carried forwards along the course of the ecliptic, from the north-west towards the south-east. This motion continues in this way; it accompanies the motion in longitude in almost every respect and adapts itself to it entirely.

[Margin: The libration is made more intricate by the motion in latitude.]

If the Moon were not at the same time subject to the motion in latitude, but were carried round perpetually in longitude in the ecliptic, this libratory motion too would be easily understood. But since the Moon, by reason of its motion in latitude, ranges now towards the north, now towards the south, and varies its nodes, it likewise comes about that this motion of libration varies from day to day for the same reason, as the motions in longitude and latitude do. So much so that it is observed differently each month, and is seen in a like configuration only very rarely, and not until many years have passed — as you will learn more fully on this subject a little later.

[Margin: The Moon's varying latitude alters the libration.]

Moreover, just as the Moon, because of its motion in latitude, both rises some degrees above the ecliptic towards the north and descends below the ecliptic towards the south, so it comes about that the libratory motion too, now towards the north,

now towards the south. That is, the libratory interval lying between the two limbs, although it is broad enough when the Moon is in Cancer, can nevertheless be widened or compressed still further according to the northern or southern latitude. And although the Moon remains in Capricorn, the circle or limb of libration of Capricorn is nonetheless changed and extended, towards either the inner or the outer part, according to the Moon's differing latitude, as I recall.

This variation of the libration occurs not only in Cancer and Capricorn but in all the other signs of the zodiac. From this it also comes about that the visible centre of the lunar disc varies and moves noticeably and plainly every month, every day, indeed every hour — as can be seen above all from the General Table of Phases and the Primary Delineation, as also in all the other lunations.

[Margin: What do those points around the centre in the General Table of Phases denote?]

In these, twenty-one points, or eighteen spaces, are seen around the centre, and they indicate the differing variation of the Moon's centre. The three upper points, that is, set on one straight line, show the centre when the Moon lingers at the beginning of Cancer. The left-hand point, towards the rising, is the genuine centre when the Moon stands in the first degree of Cancer and at the southern limit, or greatest southern latitude; the right-hand point is the

centre of the Moon when it is in the same sign and degree but in northern latitude; the middle point is the place of the centre when the Moon is near the nodes in the sign and degree already mentioned. The next three points likewise indicate the true centre of the disc, in either latitude, when the Moon is in Leo and Gemini. The third line, when the Moon stays in Virgo and Taurus. The middle one, when the Moon is at the beginning of Libra and Aries. The fifth, when the Moon is in Virgo and Pisces. The sixth, when it reaches the beginning of Sagittarius and Aquarius. The lowest, last in order, shows us its centre when the Moon is in Capricorn — on this condition, however, as already said: those seven left-hand points denote southern latitude, and the right-hand ones northern; the middle line, however, when the Moon is in the ecliptic, that is, near the nodes. But this will presently be made clearer with the help of the following figure, in which

those points of the signs and limits are represented at a greater distance; and so the motion of the Moon's centre will readily become clearer.

[Margin: The motion of the centre of the disc is explained.]

In the following diagram the left-hand line a d represents the southern limit, or greatest southern latitude, on the line of longitude; the other, opposite parallel on the right, b f, the northern limit, or greatest northern latitude; the middle one, c e, the ecliptic or line of the nodes, in which the nodes move perpetually. These three lines are divided into six intervals, or by seven transverse lines, which represent the twelve celestial signs and at the same time the Moon's latitude on either side of the ecliptic. For example, the upper line a b is the latitude line of Cancer; the one next below it, the latitude line of Leo; the third, of Virgo; the fourth, of Libra; the fifth, of Scorpio; the sixth, of Sagittarius; and the last, of Capricorn — these being, namely, the lines of the descending signs. The remaining six signs, the ascending ones, such as Aquarius, Pisces, Taurus, Gemini and Cancer, ascend again in the diagram in the same way.

Furthermore, if the Moon always completed its course either in the ecliptic, at the southern limit, or at the northern limit — that is, on lines parallel to the ecliptic — then the Moon's centre too would likewise move only on these three lines c e, a d or b f: descending from Cancer as far as Capricorn, and again ascending in the same way from Capricorn as far as Cancer. In that case not only the Moon's motion but also that of its centre would be simpler. But since, as is clear from the preceding chapter, the Moon's latitude varies very greatly every day and behaves differently from one day to the next (for now the Moon is near the nodes, that is, in the ecliptic; now it acquires a latitude of one or two degrees; now its greatest latitude, which exceeds five degrees, towards the south as well as towards the north; now its latitude decreases again), it follows that the line of longitude of the lunar centre cannot be continuously parallel to the ecliptic. It must instead make a certain angle with it and cut it at a certain time — not, indeed, always in one and the same place, as is rightly inferred from the Moon's motion, but at different points. Therefore the libration of the

centre of the lunar disc acquires a similar motion, as, from the following figure, the matter

will become clearer. And so that this might be grasped all the better, I have drawn yet more transverse lines in the same diagram, showing that mixed monthly motion which arises from the motion in longitude and in latitude. They do so not, however, in each and every degree of longitude and latitude, but only at the beginnings of the signs, where they indicate the greatest and the least variation, or change, of latitude of the Moon's centre. For to express this degree by degree in so small a diagram is certainly impossible; or at any rate the thing would produce a great confusion of lines.

Diagram. A tall rhomboid (a parallelogram leaning to the right) set at the left of the page, the text running beside it. Its left edge is the southern limit, its right edge the northern limit, and a vertical central line is the ecliptic; seven parallel transverse lines slope down from left to right across it, and a lattice of diagonals crosses between them. Each end of each transverse line carries a pair of sign symbols; the corners carry engraved cursive legends.

- a (top-left corner): with ♋ and the legend "Latitudo maxima Mer." [greatest southern latitude]
- n, t, c (along the top edge, c on the central line)
- b (top-right corner): with ♋ and the legend "Latitudo maxima Sept." [greatest northern latitude]
- Left edge, written vertically: "Limes … Auſtrinus." [southern limit]; right edge: "Limes … Boreus." [northern limit]
- Central line, written vertically: "Ecliptica" [ecliptic]
- Sign pairs at the left ends of the transverse lines, top to bottom: ♋; ♌♊; ♍♑ with a second sign [?]; ♎♈; ♍♓; ♐♒; ♈♉
- Sign pairs at the right ends, top to bottom: ♋; ♊♌; [?]♍ (first sign possibly ♉); ♈♎; ♓ with a second sign [?]; ♒♐; ♈♉
- Point letters beside the left ends: a letter [?] (possibly h) on the second line; o on the third; w on the fourth
- Point letters beside the right ends: u on the fourth line; r on the fifth
- Interior and central-line letters: s, x, m, i, a hooked letter [?] below "Ecliptica", l (near the right end of the sixth line)
- d (bottom-left corner): with ♈♉ and "Latitudo maxima Mer."
- e, g, k (along the bottom edge); f (bottom-right corner): with ♈♉ and "Latitudo maxima Sept."
- Beneath the bottom edge: "[?]ut. Sc." (unexpanded; the initial, read A in the first pass, is I, J or F by its form on a 10× re-read, and is not settled)

It must therefore be understood that the principal lines among the remaining transverse lines are a f and b d, which intersect one another, and at the same time the line of the nodes, or ecliptic, at the point g. So when the Moon is at the southern limit and in Cancer (for example at a), its centre, descending along this line in the order of the signs, librates through the node g towards Capricorn — that is, to f — where it again acquires the greatest northern latitude.

Likewise, if the Moon is placed at b, in Cancer and at the northern limit, its centre, again descending, moves through g to Capricorn and the southern limit d; the contrary happens when it ascends from f and d.

Once these two lines had been drawn, intersecting one another, other parallel lines were drawn from all the beginnings of the signs, showing each and every one of the remaining variations, and the motion of the centre, in whatever signs the limits or nodes may stand. For example: if the Moon is in Leo, and at the southern limit, then at that same moment the centre is at h, and from there it moves in the order of the signs, through the signs of Virgo, Libra, Scorpio, etc., along the line h i k. Thus the line of the nodes, or more truly the ecliptic, is cut at that time not at g (as it was before, when the limit stood in Cancer) but at i; nor does the centre return to f, the line of Capricorn, as in the earlier position of the Moon, but falls at k. From there it tends upward again to l, the place where this line of the motion of the centre touches the northern limit of the Moon's centre. From this it is inferred that the Moon's greatest northern latitude lies at this time in Aquarius, and that afterwards, from this point of contact, the centre turns again along the line l, m, n to the right, towards the upper part, to h. The opposite node on this course was at m, namely at the intersection of this line with the ecliptic, as has already been mentioned.

But if the Moon is in Taurus, and at its greatest southern latitude, then its centre stands at o, and from there it is carried upward, in the order of the signs, towards t; then it turns to s, namely the node standing in Leo; and from there again towards Scorpio, r, at which place it reaches the northern limit; and so further, by q and p, towards the opposite node, which stands in Aquarius, until it returns again almost to the place it previously held. Almost, I say, to the place it had previously left — and this should be well noted. For the Moon's centre, if you consider the matter attentively, can never return, after completing its monthly course, to that former place from which it had moved. For meanwhile the nodes are also moving against the order of the signs, with the result that the line of the centre's course is moved back a little, and at no time can it reach its limits again at the same place where it had them the previous month. This anticipation or retrocession could by no means be expressed in the preceding figure; but neither does it matter greatly that such small details be observed in this business.

As for the rest: when the Moon is in Aries and at the northern limit, you will find its centre at u, and from there it moves towards c, Cancer, and the node; afterwards it tends to vv, Libra, and the greatest southern latitude; finally, through the node e, it returns again to roughly the earlier place k from which it had departed, and so on in turn.

From all this it is certainly more than sufficiently clear that the true place of the centre, and its line of course, at any time and in all the figures of the Moon (in whatever signs the limits or nodes may stand), can easily become known without error with the help of this figure — on the express condition, which is plainly necessary, that the Moon's longitude and latitude have first

been ascertained. Moreover, from the diagram above one may also see how the visible centre of the Moon is carried round in a truly remarkable line, namely in the circumference of a rhomboid. This, however, does not keep one and the same form perpetually, but varies it each month with its proper motion: for now the rhomboid is widened, now narrowed, according as the Moon's limits occupy a different sign, or degree, of the zodiac. And it is never wider than when the limits lie in Aries or Libra, for then, as the diagram attests, the rhomboid becomes a rhombus. Furthermore, the nearer the limits are to the equinoctial points, the broader the rhomboid; but the closer they are to the solstitial points, the narrower it becomes, until, in Cancer and Capricorn, it vanishes altogether and passes into a straight line. From this it follows beyond doubt that, because the centre of the Moon's disc at no time moves in lines parallel to the ecliptic, as the Moon's proper motion does, the poles of libration likewise never remain constantly in the same place on the periphery, but now ascend, now descend, by reason of the libration of the centre and of the Moon's longitude and latitude referred to the ecliptic.

Further, I should also like to show by what method the true place of the centre is to be found in any position of the Moon, although the individual degrees of longitude and latitude are not expressed in this figure. For example, if you wish to know, for a certain

time, the true place of the periphery — that is, of the centre of the disc — when the Moon stands in the tenth degree of Leo and the third degree of southern latitude, proceed as follows. First divide the sign of Leo, simply by eye (for more exact work is not at all needed here), into three equal parts in longitude and into five in latitude, counting from the ecliptic, so that each space represents one degree of latitude. That done, fix the foot of the compasses at the point corresponding to the latitude and longitude, as here at x; from this point, as the true place of the centre, you will describe without any trouble the true periphery of the Moon that belongs to the definite and desired time. This can likewise be observed in all the figures in which the centres are marked, especially by anyone who applies himself to the matter with diligence, circumspection and attention. Above all, it matters greatly to know this: without that knowledge neither can the lunar phases be rightly observed and drawn, nor can any lunations, or observations of eclipses and so on, ever be undertaken. For unless you have first drawn the proper periphery in the primary figure, you will be building on sand, as will be said more fully later.

[Margin: How large is the space of the libration in reality?]

Now that the motion of the Moon's centre, and of its libration, has been explained to some extent, you may not unreasonably ask how large, in reality, is the part of the Moon's hidden hemisphere that this motion of libration turns towards us, and the part of the visible hemisphere that is at a certain time turned away from our eyes. From the three preceding full moons that part is in part known well enough, since the space lying between the two limbs is what is sought. For the first horizontal limb represents the appearance of the

Moon in Cancer and at the southern limit; the second, the face of the Moon placed in Capricorn and at the northern limit — the position in which the extreme bounds of the libration and the Moon's greatest variation occur. But how large that variation is, speaking exactly, in proportion to the diameter, in minutes or in German miles, I shall now disclose. At about the ninetieth degree from each pole of the Moon, where the libration is the greatest of all, near the Sarmatian Mountains [Montes Sarmaticos], and again in the southern part near the Southern Lake [Lacum meridionalem], this lunar

variation extends to about 1′ 45″ — provided, that is, you take the Moon's diameter to equal thirty minutes: this amounts to nearly thirty German miles, of which the whole diameter contains about five hundred. Around Palus Mæotis [Paludem Mæotidem], however, the libration is not so great, nor can it ever become so, because the pole is not so far from that place. For that reason the libration there spreads to only 1′, that is, fifteen German miles.

[Margin: The true interval of the libration is greater than the apparent one.]

Yet if you look into the matter more deeply, this interval of libration is far greater and wider than it appears to us, as each and every observation proves. This is judged most clearly and correctly not only from the variation of the quadratures but also from the other phases, especially the sickle-shaped and horn-shaped ones. For around the first increase of light the daily illuminated intervals are very narrow, while around the quadrature they are the most extended of all; and yet in reality, if you consider everything well, the Moon draws an equal small portion of light from the Sun on each day and in each hour, since in receding from the Sun it covers nearly equal spaces in equal times. That the phases nevertheless do not appear to us to grow or diminish in like proportion arises partly from the roundness of the Moon, and partly because the new phases have to be viewed at a more oblique angle. Thus, as regards its true, not its apparent, aspect, the Moon turns through at least 60 German miles towards one side or the other, as will be set out more fully in its place. That this space appears to us smaller by almost half arises from nothing other than this: at the time of full moon we can estimate this libration only from its appearance and from the parts nearest the periphery. And since such parts are perceived by more oblique rays than those that face us more directly about the middle, this libration (visible only near the limb) is necessarily perceived by us as smaller and narrower than if it were observed about the Moon's middle — although these intervals, compared with one another, are in reality entirely equal to each other, as François d'Aguilon

testifies in Book 6, proposition 12 of his *Optics*, where he says: *"The parts of a linear projection that arise from equal arcs of a circle are by no means equal to one another; those farther from the middle are always smaller. For the rays more remote from the centre cut the circumference of the circle at more oblique angles, and therefore stand a smaller interval apart from one another. Near the extremities, therefore, the projections of equal arcs are smaller."* This can be shown still more plainly by a drawing.

Let the semicircle d A d be the visible hemisphere of the Moon, divided into six equal parts, so that the parts a b, b c and c d are all of exactly the same size. Let E be the station of my eye, from which I view the Moon. I say, then, that although those parts are perfectly equal to one another, one part nevertheless appears larger than another; and this size grows the more, the farther the space lies from the limb d and the nearer it is to the perpendicular line a E, as is clear from the figure set alongside. For the part A b is greater than the part b c, and this in turn is wider than c d, because, as I have already mentioned, it is viewed more obliquely; and for that reason the angle of vision d E c is also much smaller than the angle A E b. Kepler demonstrated this abundantly in the *Paralipomena to Witelo*, p. 184, where among other things he says: *"When straight lines are drawn from equal arcs of a circle to a point outside the circle, the angles at the point subtended by the equal arcs are unequal, and those are greater whose arcs are nearer to the diameter through the point."*

Diagram. A woodcut set beside the text at the left of the page. A circle is crossed by a horizontal diameter and by five vertical lines; from points on the lower half of the circle, straight lines run down and converge on a single point below the circle. Labels read on the block:

- d (left end of the horizontal diameter, outside the circle)
- c (on the diameter at the left edge of the circle)
- b (on the diameter, left of centre)
- a (on the diameter at the centre)
- b (on the diameter, right of centre)
- c (on the diameter at the right edge of the circle)
- d (right end of the horizontal diameter, outside the circle)
- [?] (lower circumference, left; resembles c)
- [?] (lower circumference, left of the bottom; resembles b)
- A (bottom of the circle)
- [?] (lower circumference, right of the bottom; resembles b)
- [?] (lower circumference, right; resembles c)
- E (apex where the lines meet)
- "[?]ut. Sc." (small engraver's mark at the lower right of the block; the initial is I or J by its form and is not settled)

From this foundation, the libration of the Moon at the periphery seems to us to amount to at most 30 miles, in the upper as well as the lower part, whereas about the centre that same libration equals at least sixty, as the boundaries of the quadratures will plainly and clearly attest later on. On this occasion perhaps someone

will ask me — especially one who has weighed this matter carefully and turned it over in his heart and mind, and has not merely glanced at it in passing [per tranſennam] — why the two extreme centres of the Moon shown in the preceding full moons (the one, namely, with the Moon placed in Cancer and at the southern limit, the other with it in Capricorn and moving at the northern limit) are no farther from each other than the greatest variation of

libration in the north and the south about the periphery. For by force of the earlier demonstration, as also by the reasoning of our own view, it necessarily follows that the distance between the centres should indeed be twice as great, in longitude as well as in latitude, and that those centres should form an altogether different figure.

[Margin: On the position of the centres of libration, and why they could by no means have been set out otherwise.]

That this is so I by no means deny. But that the centres were not marked and displayed in the proportion just stated, as it really exists in the Moon, was done only for certain weighty and pressing reasons. For the true face of the Moon, with all its oceans, islands and mountains, is not expressed in the lunar figures in such proportion and form as the Moon itself has — as it would be if one could look at it from close at hand, or rather move about on it — but only as it is seen from far off, from the Earth; and so the shape, distance and proportion of those things present themselves solely according to appearance, which is all we are concerned to seek. For if the face of the Moon had been expressed otherwise, it would be of no use to our observations and our purpose, and ill suited to them. Instead of the face of the full moon being sketched as it now is, it would then have had to be drawn quite differently; and all the places situated at the periphery — Palus Mæotis, the Lacus Hyperborei, Palus Mareotis, the Insula Major of the Caspian, and so on — would have come out far larger and broader, according to their distance from the centre, and would have changed their shape altogether, for the reasons given before: the roundness of the Moon, that is, and the fact that parts nearer the periphery are seen under a smaller angle.

But since in these selenographic delineations we take account only of the visible face of the Moon — that is, how it presents itself to be viewed in the aether, and how it varies (which it is enough to have attended to here) — so too the motion of libration only,

as it appears in all the phases, that we have chosen to represent and sketch.

Indeed, the centres had to be placed in no other order and in no other form, lest at any time the true visible periphery of the Moon that corresponds to them should fail to be set rightly before the eyes by means of these centres.

As for why the sections of light and shadow [ſectiones luminis & umbræ] of the quadratures do not always pass through these centres, as by right they should: this happens because the spots, the larger and the smaller alike, by reason of libration and of their distance from the centre or the periphery, gradually spread out more and more the nearer they are carried to the centre, and are compressed more and more (in appearance, I mean) the nearer they are brought to the periphery by the motion of libration. However hard this may be to grasp at once, there is no room on this occasion to pursue the matter at greater length; I think it should simply be put off to the place where the limits of the quadratures will be dealt with expressly, so far as is sufficient.

Just as the motion of libration and of the Moon's centre varies in a remarkable way, as we have heard, according to the Moon's motion in its orbit, so too it produces various and wonderful changes about the full moons as well as the quadratures and all the other phases — so much so that hardly any phase, or any full moon, can return similar in every respect to another, even after a long interval of time has passed.

[Margin: A similar phase is very rarely observed.]

For let us suppose that, when the course of a year is complete, a phase similar to the earlier one occurs as regards longitude in the zodiac and with respect to the same time; yet it very rarely indeed happens that it is also observed at a similar latitude. And so it comes about that a full moon or any phase at once takes on a different face, and the Moon is now broader, now narrower, now above, now below, now towards the east [Eoum], now towards the west [Zephyrum], as is gathered without difficulty from the libratory motion. The quadratures too, whichever occur in the year, are constantly subject to similar variations. From this it also follows that one similar to another is seldom seen — and not only because, by reason of libration, it grows or shrinks in the upper part or the lower, or on either side, but above all because the sections of light and shadow cut across the Moon in a wonderful way at the time of quadrature: while the section of

[Margin: The quadratures, too, vary greatly.]

illumination extends now more towards the east, now towards the west, and now the Moon, in respect of the figure, is cut into two halves. Meanwhile, however, this variation and alternation keeps to its own fixed limits, and to a time within which all of this is completed.

[Margin: The boundaries of the quadratures swing back and forth at a fixed time.]

For just as the quadratures stay in the ascending signs for the first half-year and travel through the remaining, descending signs in the other half-year (since each month the quadratures move round into one sign after another, in the order of the signs [in conſequentia]), so in a similar way the sections of the quadratures advance, counting from the month of March (when, about the equinox, they occur in Cancer), from west to east, following the sequence of the signs, until about September, when the quadrature [Quadra] rises in Capricorn; for at that time these sections run back again in a similar way, all the way to March. That it has not happened otherwise up to now I have learned with the greatest certainty from countless observations, a good number of which I have chosen to set before the eyes of those who cultivate astronomy in this treatise as well, so that anyone may perceive and understand everything all the better, and the motion of libration, or reciprocation, may be more firmly established.

For this reason I decided — having delineated six quadratures, namely the tenth, the eleventh, and figures 12, 30, 31 and 32, which represent the greatest variation — to publish at the same time several whole lunations, observed with

the utmost care within the space of a month. From them, those wonderful monthly progressions and retrogressions of the sections of the quadratures, in almost any signs whatever, may be grasped by the very sense of sight; and likewise there may be noticed, over almost the whole course of a year, not only the motion of variation, or libration of the horns (which will be dealt with fully below, in chapter 18), but also the change and alternation of all the phases themselves, and the motion of reciprocation of the centre. I do not doubt in the least that anyone will find everything I have reported and set forth to be well observed and grounded in the heavens — provided that account is taken at all times of the longitude, the latitude and the nodes of the Moon.

[Margin: The author observed whole lunations in a particular way.]

This method of observing the individual phases — or rather the sections of light and shadow — recurring daily over the space of a month, a method set up with the help of some primary and corrected delineation designed for this work, I judge will bring a great deal of benefit and to be supremely necessary. And it serves not only to explore the various changes of the phases, as I judged, but also, by this single means (provided only that the business is diligently kept up), to investigate correctly the motion of libration in longitude, in latitude and of the horns, as well as to come to know the other phenomena that occur around the Moon and the differences of the diurnal arcs. Had I not used this technique myself, I could scarcely have produced even a lightly worked-out Selenography in so short a span of time spent on the matter. Nor do I have any doubt that, if observations of this kind are continued by others, perhaps still greater things will be found. At the very least, those who are still in some doubt about the certainty of the motion of libration, or of the variations or changes of the phases and what depends on them, will certainly become better assured on this matter once they know that everything I have put forward here for the first time rests on a solid foundation, and that nothing fictitious is being handed down.

[Margin: These observations contribute a great deal to selenography and astronomy.]

The way in which observations of lunations of this kind should be set up correctly and conveniently will be taught in chapter 44. To that place is also reserved the general, or primary, figure adapted to lunations and other observations, together with all the observations required. As for a fuller demonstration of the limits [terminorum] in the quadratures, and also of the motion of libration of the horns, and further a sufficient exposition of the quadratures themselves, we shall reserve these for the description of the figures, since it has not been possible to explain and demonstrate each and every thing at once in this place.

Now that the spots have been given suitable names, and the motion of libration has been unravelled and explained sufficiently, I believe, for the purpose of our undertaking, I set about saying some things once more on the delineation of the full moon: on the true proportional measure of the spots and the shape of

their arrangement, their colours, changes and properties, on the Selenographic Map itself, and on matters bearing on these.

For although a reader eager for these matters may, even without a guide, in some measure grasp with his eyes, from the larger ichnographic map that shows the delineation of the full moon, the proportion and symmetry of the spots — that is, of the seas, lakes, bays, mountains and valleys, and of the other things met with on the face of the Moon — which I have sketched with the greatest care and diligence, he will still in no way grasp with his mind from what has gone before, unless he is told, by what aid I was able to observe that accurate proportion and disposition of the spots. Unless I am entirely mistaken, he will perhaps think it scarcely possible that I could have determined this proportion, having persuaded himself that I carried out these observations solely with the help of the tube, measurement by eye and simple inspection — a way so very slippery that anyone could easily be deceived and misled in delineating the phases, as one may gather clearly and openly from things constantly before our eyes.

[Margin: How the proportion of the spots may be investigated by an infallible method, and most accurately.]

I certainly do not deny that it is extremely difficult, by simple measurement with the eyes through the telescope, to put on paper the due and true form and proportion of any object; I found this out myself, more than enough, at the beginning of my observations. For that reason I saw that an entirely different, and safer, way had to be taken, by which I might be certain of the measurement of my eye, and, with everything well examined, might furnish all the phases, established by an infallible method, in such a way that it could be demonstrated to everyone concerned that they had been correctly delineated, so that no one would have any right to object. This, then, is how I set about the matter.

First, in the observations and delineations of the spots, I paid attention with the greatest diligence and industry, and noted carefully which places lay on one and the same straight line. At the very first glance a huge number of them revealed themselves, which are found in a similar arrangement together with three, four or five other prominent places. For example — to mention only a few, so that the matter may be grasped the better: 1. On the same straight line are seen Mons Ætna, Insula Besbicus, Insula Cyanea and the northern shore of Palus Mæotis. 2. Mons Sinai, Mons Didymus and Insula Macra. 3. Sinus Maris Pamphilii, Mons Mesogys, Mons Argentarius and Lacus niger minor. 4. Mons Porphyrites, Insula Corsica and Insula Macra, the southern part of Insula Sardi-

[Margin: Which spots lie on a straight line?]

nia, and the foot of Mons Argentarius. Many more such places are found that run in a straight line in the same way, as I shall relate a little later. This is indeed the best aid to arranging any spots whatever exactly; and yet it is still not wholly sufficient, since by this way no spots that are to serve as a foundation can yet be set in their true and genuine place. I therefore set about accomplishing the matter by following the practice customary among geographers when they

undertake to draw and construct a geographical map. They first ascertain the longitudes and latitudes, if not of all places, then at least of the principal ones; once that is done, the task becomes very easy. For if those places are simply set at the right-angled intersection of the lines of longitude and latitude, their true and natural position has been found; and so one proceeds in turn with the rest whose longitude and latitude have become known.

I therefore followed almost the same method in investigating the regions of the Moon. For although (as you will readily understand) the longitudes and latitudes of places on the Moon cannot be traced in quite the same way as geographers may trace them from the known distance between routes — since on the Moon access to those places lies open not to the feet but only to the eyes — nevertheless, just as in geography there are still other ways of exploring the distances of places that cannot be reached, so in selenography too there are not dissimilar ways by which the position and distance of the lunar spots can be learned without a great deal of trouble, as I shall now explain.

To begin with, I investigated diligently which places on the Moon lie at some intersection of two or three definite lines. Among others, for instance, Insula Besbicus of the Propontis is noted. As I have already mentioned, it forms a straight line with Mons Ætna, Insula Cyanea and Promontorium Arietis; but it also forms, likewise, another straight line with Insula Corsica and Mons Herculis, and in turn a third with Insula Macra and the outermost tip of Sinus Strymonicus, so that this island lies exactly at the point where three lines intersect one another. Similarly, this Besbicus, in my lunar diagram, under the same intersection

of the three lines mentioned lies — and since it does, this is a most perfect and infallible sign that the island has been set in its due and proper place, and also that the other regions already mentioned have been correctly placed. If, however, some error has crept in during the drawing, it can be forestalled by this method without great labour.

Second: I found that Mons Didymus of Asia also lies at such an intersection of two lines. That is, I found it on one and the same straight line with the outermost tip of Sinus Strymonicus, Mons Sipylus and Lacus Thospis, and also on a straight line with Insula Macra and Mons Sinai. Very many more places on the Moon stand in this relation to one another, but I gladly refrain from listing them so as not to be long-winded. It is enough to have shown the path I trod, so that I was able to set the regions of the Moon accurately and correctly in my lunar figures [Iconismi], to tie one spot to another, and to correct errors that crept in from time to time. To carry this undertaking more correctly to its end, I enlisted the help of all the places lying in the same way that I could ever find; places situated otherwise I attached to those already known and correctly placed, either by straight lines or by an accurate estimate of the eye.

Third: if two, three or more lines meet at a single point on the Moon, and this appears in the same way in the phases I have drawn, that too is a most certain and infallible indication that those places have been correctly arranged.

Of such places, holding precisely this kind of position, a by no means small number is likewise found — among others, Insula Macra, Mons Ætna, Mons Sinai, and so on.

[Margin: Another method of measuring the distances of places on the Moon.]

Fourth: I found, besides, a singular shortcut for advancing all these things more successfully and more accurately. By it, as by an instrument, we cannot fail to measure, investigate and judge the distances of various places on the Moon — not with the astronomical cross-staff [Radius Astronomicus], the astrolabe, the sextant or other instruments of this kind, but solely with a good and properly fitted telescope. It is done in the following way. All tubes, however long and excellent, never take in the whole diameter of the Moon at one time; rather, the stronger and finer they are, the smaller the portion of the Moon they show us. I therefore very carefully

considered those places on the Moon that lay within the same aperture of the tube as being equally distant from one another and wholly alike in their distance. Afterwards I examined whether my drawn figures also showed the same appearance. In this way I made many observations with different apertures of the tube. Having done so, I was able to draw my phases, to correct them once drawn, and to examine them once corrected, so that there is now no further room for doubt about their true proportions [symmetria].

So that it may be shown still more clearly to the cultivators of astronomy and the observers of the stars that both the full moons I have depicted and all the other phases displayed in this work have been sketched most accurately — and so that they themselves may at the same time be able to weigh them quite strictly, with the help of an excellent telescope, against the true primary figure, that is, the Moon's own native face — I shall for this reason list here also the remaining places on the Moon that lie on straight lines, since the lunar figures rest very heavily on these pillars. For then anyone will be able, by his own efforts and without difficulty, to test any drawn figures whatever with a straight ruler and to compare them with the Moon itself. He will no doubt find that I was extremely careful and exact in this business (let there be no vain boasting, however), and that I strained every power and sinew to the utmost to leave out nothing at all that might serve this work. Nor will the benefit that flows from this to observers be small: so instructed, they will know how to examine correctly the phases of others that are put before them. For if all the places are not set on their straight lines, it will become absolutely certain to them both that the observation is faulty and that no small error has been made in drawing it.

[Margin: Which spots form a straight line?]

Besides the places mentioned before, the following also form a straight line. 1. Lacus niger major, Insula Macra, and the tip of Palus Mæotis that faces toward the north-west. 2. Mons Serrorum, Promontorium Lunæ and Insula

Corsica. 3. The middle of Insula Cercinna, Mons Ætna, and Archerusia Palus by the Pontus. 4. The outermost tip of Sinus Strymonicus, Mons Sipylus, Mons Didymus and Lacus Thospidis. 5. Mons Horminius, the uppermost of three, M. Olympus, M. Sipylus, Insula Lesbos, Insula Creta, Paludes Arabiæ and M. Casius. 6. Insula Melos, Insula Rhodus, Mons superior Libanus, M. Antilibanus and Mons Armenius, which can be seen in the drawing of the ichnographic full moon. 7. Mons Sinai, M. Cataractes and Palus Mareotis. 8. Palus Mareotis, Sinus Syrticus and M. Ætna. 9. Promont. Apollinis, Promont. Lunæ, Insula Cyanea, and so on. Many other spots of this kind are still to be found on the Moon, however, and a diligent lover of the stars [Aſtropholus], accustomed to labour, who has an interest in knowing these things, will search them out for himself.

[Margin: Seas, marshes, mountains and valleys differ in colour.]

But to return to the description of the Moon itself, I repeat once more what I mentioned already in Chapter 6: namely, that the large spots that are visible at full moon even without a tube are oceans, and that those whitish and more brilliant places are mountains, valleys and plains. The reasons from which this is inferred appear to have been explained sufficiently in that place. As for the marshes, they do not present themselves on the Moon as so dark as the seas and lakes, nor so luminous as the mountains, valleys and plains. The reason is ready to hand: they can return the Sun's rays more strongly than the seas, but not as well as the land of the Moon — because, that is, of their greater and lesser opacity.

That the valleys are very white and shining at full moon, but otherwise when the Moon is waxing or waning, arises from this: at that time the Sun pours its rays straight in, so that the rays are reflected on all sides to the surrounding mountains; and since, by reason of the mountains' various inclinations, these rays are carried back into the valley, these valleys must necessarily scatter a greater and stronger light than the other places, which are levelled and less rough. That the valleys appear most shadowed on the right when the Moon is waxing, and on the left when it is waning, comes chiefly from the shadow of the loftier mountains, which in that position deny the Sun's light the passage by which it might reach into the valley. This becomes plain from the diagram placed alongside, in which A represents the Sun, and B, C, D are three valleys surrounded by very high mountains. Valley B the Sun, from the right, illuminates, like all the valleys of the waning Moon. Valley C, or rather mountains C, are lit in the opposite way, because they lie towards the other quarter with respect to the Sun, as all the mountains of the waning Moon do; and so the shadow too turns itself entirely the other way. D represents a valley which the Sun lights as if from the point of the zenith — or, to speak more correctly, a valley which lies on a straight line with the Sun and our eye. At that time, therefore, as at full moons, no shadow at all is detected there; such valleys necessarily appear wholly luminous, shining and whitish.

Diagram. A small rectangular engraving set into the text at the upper left, its dark ground shaded in horizontal hatching. Along the top stand three discs: at the centre the Sun, drawn as a rayed disc; to its left a ring whose inner dark crescent lies on its right side; to its right a ring whose inner dark crescent lies on its left side. Below the Sun stands a plain white disc. An engraver's mark stands in the lower right corner.

- B (top left): the valley lit from one side, its shadow on the right
- A (top centre): the Sun
- C (top right): the valley or mountains lit in the opposite way, the shadow on the left
- D (lower centre): the valley lit from straight in line with the Sun and the eye, with no shadow
- "Aut. Sc." (lower right corner): engraver's mark

This is clearly gathered from the mountains and valleys of all the phases: these mountains and valleys, because of their shadow, are subject to a greater change in appearance than the seas and pools, which keep almost always the same colour. *Almost*, I say — and let this be well noted — the seas, lakes and marshes keep their colour, but nevertheless not completely, and not at every time.

[Margin: Seas, lakes and marshes change their colour somewhat at different times.]

For, first, the nearer they are to the boundary between the luminous and the shadowed part, the more they vary in colour, and for the most part they then appear fainter. The same happens if those spots lie very near the periphery: for at that time the Sun's rays fall on them more obliquely, as is observed in the horn-shaped and sickle-shaped phases. Second, this happens because they are likewise viewed at more oblique angles, so that they cannot communicate so strong a light to us as if they were viewed more directly. This follows from the optical axiom: "Everything visible is seen less when viewed obliquely than when viewed directly"; and: "The more directly a thing is set opposite, the more perfectly it is seen" (Mersenne, Theorem 8, p. 496); and also from the one the same author mentions in the *Ballistica*, page 78: "Things illuminated obliquely are lit more feebly."

[Margin: The more obliquely anything is lit, the more feebly it is lit.]

This is made still more open and clear by the accompanying scheme. For example, let AB be some plane onto which all the rays E, F,

fall. BC is another plane again, on which, however, the rays cannot strike perpendicularly, since it is exposed to them more obliquely; and for this reason not all the rays fall on it either, although, as can be seen, it is of exactly the same length as the former plane, AB. Fewer still are spread over the plane BD, because it is set at a more oblique angle. AB is therefore lit the most perfectly and clearly of all, since all the rays travel to it perpendicularly. From this, then, it may plainly be gathered why seas and marshes situated near the periphery,

or carried there by the motion of libration, do not appear to us so dark and distinct.

Diagram. A tall, narrow engraved rectangle at the upper left of the text, filled with vertical hatching that represents the falling rays. Its top edge runs from A at the upper left corner to B at the upper right corner. From B two straight lines descend to the left: one to C, on the left edge at about mid-height, and a steeper one to D, lower down and a little inside the left edge. Small, faint letters stand in the two bottom corners.

- A (top left corner): end of the plane AB
- B (top right corner): common end of the planes AB, BC and BD
- C (left edge, mid-height): end of the plane BC
- D (lower left, inside the edge): end of the plane BD
- E (bottom left corner): ray
- F (bottom right corner): ray

This phenomenon is plainly observed in the Palus Mæotis [Palude Mæotide]. For when the Moon is in Cancer, at which time the Palus is farthest from the western limb by reason of libration, it is then darker, more noticeable and more conspicuous than when it stands in Capricorn — as is clear from almost all the figures, unless perhaps they happened to be printed too dark in the press.

[Margin: Why the mainland of the Moon does not change its colour as much as the seas and marshes do.]

That such a difference and noticeable faintness does not show itself equally in the mountains and valleys, whether they are found near the periphery or near the middle (for in every place they are always seen equally shadowy), arises from this: the mountains and valleys consist of a very rough and rugged surface, composed of innumerable planes according to an innumerable diversity of inclinations, as was already said above in Chapter 6. The result is that, thanks to this roughness, they can transfer their rays to us equally well, whether those rays proceed more obliquely or more directly with respect to us. This is impossible in those great spots, because of their flatness, that is, and their great evenness.

Moreover, near the Moon's margin the larger spots (or seas) are not only fainter; they also appear much more compressed than when they are somewhat farther from the limb by reason of libration, as all the observations confirm. For when the Moon stands in Cancer, the Palus Mæotis, far wider and blunter,

is seen both at its upper and at its lower part than when the Moon lingers in Capricorn; this is seen especially clearly at the summer and winter full moons. Nor indeed is something of this kind noticed only in the Palus Mæotis; it is noticed also in the other spots nearest the limb, namely the palus Mareotis, the Lacus hyperborei, and so on.

[Margin: The nearer the spots are to the limb, the more they are compressed.]

Furthermore, such a change of form and figure, arising from the libratory motion, is also detected in the mountains and valleys, so that the mountains and valleys nearer the periphery appear to tend more towards an elliptical figure than those around the middle of the Moon. This is clear from all the phases and

full moons, but above all from the Insula Maris Caspii, the Montes Paropamisi, Mons Meridionalis, M. Troicus, M. Techisandam, Mons dalanguer and others. Otherwise, around the middle of the Moon, the valleys for the most part appear round: for example Insula Besbicus, M. Sipylus, M. Didymus, M. Olympus, and also the remaining valleys and islands. The reason may easily be sought from the figure on p. 247. For the nearer anything is to the periphery of a round body — the Moon, that is — the more obliquely we see it, so that everything situated at the limb, whatever comes into view, necessarily appears more oblong and more slender, although in reality it is perfectly round. For *a circle viewed obliquely appears as an ellipse, and an ellipse, with the eye in a certain position, appears as a circle*: this is an optical theorem.

On this occasion a notable question presents itself: why, namely, are almost all the valleys and islands around the middle of the Moon seen to be of a round figure?

[Margin: Why the lunar valleys and islands around its middle mostly appear round.]

First, indeed, it can be beyond all doubt that the Moon is joined to our Earth by a great affinity, especially in respect of its mountains, valleys and islands; and for that reason those mountains, etc., ought rightly to produce an effect similar to these terrestrial ones of ours. Yet terrestrial valleys and islands are rarely found to be round in figure; for the most part they are angular and marked by many windings and promontories, as experience itself testifies. Just as I do not deny that this is so, so I am wholly of the opinion that the lunar valleys and islands are filled with windings, angles and promontories just as great as our terrestrial ones are — indeed,

all of them, almost, are of irregular figure. That we cannot discern such things so distinctly comes from that great and incredible distance, from the weakness of our eyes, and from the imperfection of telescopes. For if the Moon were much nearer the Earth, and the tubes stronger and more perfect, I do not doubt that even the very smallest things of this kind would be noticed by us. Moreover, the farther off an irregular figure is, the more it approaches roundness; and so it comes about that the lunar valleys appear for the most part round, without angles and windings.

[Margin: Valleys round in form exist both on the surface of the Moon and on that of the Earth.]

Nevertheless, it is not altogether denied that here and there on the Moon there may be valleys that are round in appearance, and in plenty, just as on this terrestrial globe of ours. Here certainly not a few are found that are enclosed on every side by mountains of wonderful height, so that they present almost the same round face as those visible in the lunar phases and on the Selenographic Map; this is abundantly clear from the terrestrial globe and from many special geographical maps. Very notable valleys of this kind, of circular figure, are found both in Persia and in other regions: namely, 1. the desert Turbet; 2. the desert Mingui; 3. in Germany, the kingdom of Bohemia; 4. the kingdom

of Berdoa and the kingdom of Zanfara in Africa; 5. in Tartary, the desert Belgim; 6. in America, and specifically in the kingdom of Peru, a very vast valley near Quito and Cuenca. Far more of them could still be pointed out by name, especially if one had a mind to travel through and survey Switzerland, Piedmont, the County of Tyrol, Styria and Transylvania.

Furthermore, as regards the Selenographic Map, and the lofty mountains expressed on it in the orthographic and geographic manner, this above all is to be noted about them: the mountains to be seen there have not been drawn to a certain and definite number, as if neither more nor fewer were to be found on the globe of the Moon. For this is impossible to do not only for the lunar mountains; even with terrestrial ones no man can achieve it. Certainly no geographical map has ever been produced on which each and every mountain is marked. For all mountains whatever on the surface

of the earth, to count or to depict them is of the kind of thing that cannot be done. It is enough that either the more notable ones, the principal ones of all, or the ranges of mountains or the forms and figures of the valleys be sketched in outline. This has been done here for the Moon too: in its delineations, and especially in that Selenographic Map, the figure of the valleys, the smaller as much as the larger, has been observed and portrayed most accurately and with the greatest diligence; nor have any mountains been drawn in any place where they are not actually found. But if you ask where I drew all this from, I would have you know that I obtained it most correctly solely by means of the following forty phases. The full moons certainly contributed nothing whatever to this business: for at that time the valleys are just as bright as the mountains, so that the valleys can scarcely be distinguished from the mountains. But, as I have already mentioned, around the boundaries of light and shadow in the remaining phases, when the valleys show themselves full of shadows, the traces of the mountains at once appear plainly, both of the higher and of the lower ones, and of those that surround a large or a small valley. If you survey all the phases diligently in this way, weigh them carefully, and compare them with the Moon itself, you will be able to construct a Selenographic Map of this kind successfully.

[Margin: The general Selenographic Map of the phases: how, and to what end, it was constructed.]

But so that the devotee of the science of the stars may the more readily understand and perceive whether these various and innumerable mountains and valleys have also been duly placed, and all inserted in that earlier Selenographic Map (for, so far as I know, I have willingly omitted nothing), I shall therefore set out in this place a General Map of all the phases. In it all the mountains and valleys visible day by day are represented in the way in which they are otherwise seen in the remaining phases around the sections of light and shadow. At that time the true size of the breadth of the valleys, which they display around the summits of the mountains, is detected; and then too they are most notable, since at no time are they suffused with greater shadow. It is indeed

impossible for the Moon ever to present itself to view with such a face, because it is round, and not at all a flat body; but this Map of ours is given so arranged as if the

hemisphere of the Moon were a perfectly flat body that could be illuminated and shaded in this way (if I may so speak) by the rising Sun. And it has been composed precisely to this end. First, so that the genuine form and figure of all the valleys and mountains existing in the visible hemisphere of the Moon may be contemplated at one time together, and indeed in such a form as they present themselves little by little from day to day, as usually happens in the phases around the limits of light and shadow. Second, so that we may have a kind of figure of all the phases and, properly speaking, a primary figure, or fundamental ground plan [Ichnographicam], of each of the mountains and valleys, as they actually appear in the sky when they are most shaded. Third, so that it may be plain to anyone at the very first glance from where those mountains, and their ranges, in the earlier Selenographic Map were derived and drawn; and likewise from what foundation that other primary figure was constructed (the one we otherwise use for observations and lunations, as will be said more fully in chapter 44). This General figure sufficiently shows all these things to anyone who considers and weighs them accurately. Finally, it will also be very useful and necessary for examining other phases against it, so that names may be assigned to the mountains the more deftly and committed more easily to memory, since it does not cause as much confusion as the earlier Selenographic Map.

[Margin: The face of the General Map presents the appearance, as it were, of a waning Moon.]

Moreover, let the students of the stars know that I constructed this Map with the greatest care and industry, and knowingly omitted nothing whatever that was notable on the Moon, or that could be found and made out with the best tube. In this figure the shadow of the valleys indeed proceeds from the left, so that it in fact represents the Moon, or more truly the phases, waning; but if you imagine the shadow on the right, you will have the Moon waxing, as you easily gather. By means of both circles (as in the two preceding figures) I have similarly expressed the greatest and the least libration; the limb has likewise been divided into its degrees, according to the order of the signs. I placed the first degree around the middle of the Lacus hyperboreus superior and the Palus Amadoca (since above all the lake already mentioned is very notable, and nearest the periphery, and

Diagram. Fig. R, the General Selenographic Map of the Phases, a double-page engraved plate of which this page carries the left half; it continues on the facing page, where the caption "Fig. R" stands. The lunar disc fills the right of the leaf. Its plains are shaded with dense parallel hatching, while the mountain ranges, ridges and the rims of the many craters are drawn light, each crater with a hatched shadow inside it. No place-names are engraved on this half. Two graduated rims, each a chequered band numbered in tens, run round the

left limb of the disc. They are not concentric and appear to cross in the upper left. At the top left two flying putti hold up a cloth bearing the title. At the bottom left one kneeling putto draws with a pair of dividers on a board held upright by a second putto, who rests a hand on a book; beside them stand a small globe on a stand and a long straight rule, and beneath them is a scale bar.

- Title on the cloth, top left: *General Selenographic Map of the Phases, drawn as a ground plan [Ichnographice] with the help of the telescope, with the greatest and the least limit of libration, observed with the greatest diligence, and engraved in copper by Johannes Hevelius, in the year 1645.*
- Scale bar, bottom left: German miles [Milliaria Germanica], numbered 10, 20, 30, 40, 50, 60, 70, 80, 90, 100.
- First rim (outer at the top), numerals in order along the line from the top right: 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210.
- Second rim (inner at the top), same order: 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210.
- At the right edge, beyond the second rim's 40: one numeral cut off by the edge, 3[?].
- A small light mark shaped like a figure 4 on the disc, upper middle: [?]; dark marks near the gutter on the right edge, mid-height: [?].

Fig. R continues: the right half of the double-page plate begun on the facing page. The rest of the lunar disc fills the left of the leaf, again with no place-names engraved; the two graduated rims continue round its right limb. At the top right two flying putti hold up a cloth bearing a verse of scripture. At the bottom right one standing putto looks through a telescope, while a second kneels on all fours with his face at the edge of a small cloth-covered table on a turned pedestal; beneath them is a second scale bar. The caption stands at the bottom centre.

- Verse on the cloth, top right: *The great works of Jehovah, set forth for all who delight in them. Psalm 111, verse 2.*
- Caption, bottom centre: Fig. R
- Scale bar, bottom right: *Ecliptic digits and their segments* [Digiti Ecliptici et eorum fegmenta]; the whole digits are numbered 1, 2, 3 above the bar, and the segments within them 30 [?], 60, 30, 60, 30 on the bar.
- Rim outer at the top, numerals in order from the top left: [?] (cut at the fold), 30, 20, 10, 360, 350, 340, 330, 320, 310, 300, 290.
- Rim inner at the top, same order: [?] (cut at the fold), 20, 10, 360, 350, 340, 330, 320, 310, 300, 290.
- Lower right, where the two rims run close together: 280, 280, 270, 270.
- Lower arc nearer the disc, from the right: 260, 250, 240, 230, 220, [?] (cut at the fold).
- Lower arc farther out, from the right: 260, 250, 240, 230, 220, 210.
- Small dark marks near the gutter at the left edge, mid-height: [?].

This leaf is blank: the back of the Fig. R plate, with the engraving showing through in mirror image.

of perpetual appearance, whereas other spots situated at the limb are very often hidden), so that a straight line can be drawn from the centre through both the Lacus hyperboreus and the Palus Amadoca. Yet it would have come to the same thing even if I had begun numbering the degrees from some other point, provided only that the spots are fixed to a definite place.

Last of all, I set before you two scales drawn on this Map: partly so that you may measure the distances of places at will, and partly so that you may well be able to determine the magnitudes of eclipses and of other observations, etc., all the more accurately.

[Margin: The latitudes of the valleys are shown on this Map as they are bounded around the summits of the mountains.]

But now let us go further and settle a question very well worth knowing: from what source, namely, have we been able to gather such certain and accurate sizes of the valleys, both on this Map and on the Selenographic Map? For it has been established more than sufficiently, from the daily phases as well, that the valleys do not keep one and the same size and shape perpetually, nor from day to day; rather, as the Moon waxes they decrease more and more, and as it wanes they grow again — that is, in step with the increase and decrease of the shadow. This is seen quite plainly in the tenth, eleventh, twelfth, thirteenth, fourteenth and fifteenth figures, and also in the twenty-fifth and twenty-sixth, above all in the Valles Uxiae, Coibacaranae, Dalanguerae, Techisandarae, etc.

[Margin: What is the reason that the lunar valleys appear to grow and to diminish?]

I answer: these valleys, and very many others, are seen to be larger as regards their upper circumference — the one, that is, that shows around the summits of the mountains — the nearer they stand to the boundary between the luminous and the shadowed part; but the farther they are removed from the limit of the light, the more they decrease, until, around the full moons, they almost entirely vanish. In such a proportion, therefore, as they decrease while the light grows, so in turn, as the light diminishes, they continually grow. This is certainly a quite remarkable thing, and I hold it as quite certain that its explanation is not seen through and understood by just anyone. For my part, observing all these things and weighing them more exactly, I could grasp in my mind no cause other than the one I shall at once set out. Namely, since all the mountains without exception, especially the sandy ones, rise to a point like a cone [in metam faſtigiati] (for the higher they rise, the sharper they become), it therefore follows that when the valleys,

are nearest the sections of light and shadow — where the Sun first begins to light them up around the summits of the mountains — they then appear very spacious, as can be seen in the preceding figure. But the farther they are moved from that boundary, the higher the Sun climbs above the mountains and the more deeply it illuminates the valleys. For this reason the valleys are, in

appearance, as it were compressed, so that they necessarily look smaller; and the situation and shape of the mountains also contribute not a little to producing this appearance. At the time of full moon, however, when these valleys are lit up on every side by the Sun's light (that is, when the Sun stands almost vertically over them), they then acquire the same light as the other, more elevated places; so it is no wonder that they are seen, and distinguished from the higher places just mentioned, only with great difficulty. The same thing is observed in the valleys while the Moon wanes, but in the opposite manner.

[Margin: Crags, too, are presumed to exist on the Moon.]

But indeed, that something of this kind does not appear in all the valleys perhaps arises from this: not each and every mountain rises to a similarly pointed summit; rather, perhaps, very many are of the same kind as the crags, rocks or rocky mountains among us, which for the most part rise almost straight up, so that they are sometimes found to be little sharper at their top than at their foot. So around mountains of this shape no such great change arises from day to day as around the sandy mountains, which taper like a cone [in modum metæ] to a sharp summit from a fairly broad base.

[Margin: By the aid of geometry the heights of the lunar mountains can be measured by an infallible method.]

But although much still remains to be said, both about these mountains and valleys and about other things that depend on them, we shall nevertheless reserve these to be treated in the following chapters. In them not only will the phases themselves be set before the eyes, but all the rest as well, of which not enough has yet been said, will be explained more and more fully. But before an end is put to the present discussion too, we think it not beside the point, prompted by this convenient occasion, to mention likewise how great a height the lunar mountains already mentioned, and those crags and rocks, may have, and moreover to point out various methods by whose help, both optically and geometrically, without any

risk of going astray, we can measure and determine their true and genuine height — and indeed as correctly and accurately as if they stood on the Earth's surface and were viewed by us at close range.

To not a few, and above all to those who are little skilled in geometrical and astronomical matters, this undertaking of ours will seem not only difficult but altogether futile, considering that the mountains whose height we wish to give cannot be adequately reached even by the eyes, let alone by the feet. In truth, however, the thing is not altogether impossible to do, as those more skilled in mathematics understand: for with the help of geometry, by far the most excellent of the sciences, a way lies open for the mind to reach even these things that are remote from our senses and our body — provided, that is, that the data the geometers demand are certain.

[Margin: Luminous points visible beyond the boundary are the summits of mountains.]

First, that very lofty mountains and crags exist in abundance on the lunar surface is beyond doubt. This proves itself sufficiently even to the eye, above all from those bright and luminous small areas [areolis] that are visible beyond the boundary of light, in the dark part of the waxing or waning Moon; it was also amply set out in the sixth chapter. These luminous points are nothing other than the summits and peaks of upstanding mountains; and since they are higher than the rest of the Moon, they are therefore necessarily also lit by the Sun sooner than the valleys and the adjacent places that are lower or flatter.

[Margin: The higher the mountains are, the sooner they enjoy the Sun's light.]

Moreover, the more elevated the mountains are, the sooner they are struck by the Sun's rays, as reason itself confirms. It follows, therefore, that the loftier mountains of the Moon are not only suffused with light sooner, but are also seen and observed farther from the limit of light and shadow than the rest — which is most true, beyond any contradiction.

Accordingly, once it is known how far the peaks of the mountains stand from the boundary of light and shadow, whether in miles or in proportion to the Moon's diameter, a certain datum is at the same time also known, on which we can safely rely and take our stand. This is learned quite accurately from the phases, and especially from the quarters [Quadraturis]; but the true distance of the summits of the mountains, or of the illuminated points, is rightly perceived only around the quarters [Quadras]

since at that time they are presented to the eyes more directly than in the other phases, whether waxing or waning. In those phases, therefore, the distance necessarily appears smaller, because it is viewed more obliquely and under a smaller angle of vision.

[Margin: How great is the greatest distance of the illuminated points from the limit of light?]

The true distance of the illuminated points from the boundary of light and shadow, especially at the time of quadrature [Quadraturæ], is found to amount to one twenty-sixth part of the whole Moon's diameter, namely when they are at their farthest. This is demonstrated most clearly from the thirty-second phase and Mons Apenninus; from the thirty-first phase and Mons Didymus; and from the thirtieth phase and Mons Taurus and Antitaurus. This part of the diameter came to nineteen German miles, of which the whole diameter of the Moon contains 494 — that is, when those small areas stand farthest of all from the limit of light. Meanwhile, however, others too are found that are not so far removed, but only by one thirtieth part of the diameter; others by only one thirty-fourth part; indeed others by a mere one fortieth part of the Moon's diameter; and sometimes they are even less distant. By reason of this distance, therefore, some mountains are higher than others, just like the mountains of the Earth.

Although the distinguished Galileo Galilei, and others who have followed him, such as Giuseppe Biancani and Bettini, do not agree with me on this point

— as can be seen from Galileo's *Sidereus Nuncius*, p. 24, where he asserts that the distance of the mountain summits from the boundary of light and darkness, mentioned above, extends to one twentieth part of the lunar diameter — I say, on the contrary, that the distance seen farthest of all from the boundary does not exceed one twenty-sixth part of the diameter. This we can demonstrate to the eye, beyond doubt and openly, from all the observations of the Moon; nor will others in truth ever find it otherwise. Since the distances we have assigned are slightly smaller, the mountains too are therefore found to be somewhat lower than Galileo estimated. And yet, most deservedly, they can not only be equated in height with our earthly mountains, but are certainly far higher than the greatest of all of ours, as will at once be clear from the diagram added here.

[Margin: How the heights of the mountains of the Moon are to be computed.]

From this, too, it is easy to show in various ways how it is not beyond us to investigate the heights of the lunar mountains — that is, how great they are along the perpendicular line, which must always be attended to whenever we speak of the heights of mountains.

Diagram. An engraved inset, set in a plate-mark frame at the left of the text, showing the Moon's globe as a circle. A rayed solar disc at the top left sends a horizontal straight line that touches the circle at its top and runs on to a shaded mountain drawn on the upper right of the circle. A vertical line runs from the point of contact through the centre to the foot of the circle, and a straight line joins the centre to the mountain. A small italic engraver's note stands at the lower right of the frame.

- D (above the solar disc, top left): the Sun
- B (top of the circle, where the line from the Sun touches it)
- C (right end of the line, beside the mountain on the upper right)
- G (left side of the circle)
- A (centre)
- F (right side of the circle)
- E (foot of the vertical line, bottom of the circle)
- Aut. Sc. (lower right of the frame): engraver's note, as printed

Here is the circle BFEG, which denotes the convex surface of the lunar globe; D denotes the Sun, whose rays, going out in a straight line, touch a lower place of the Moon at B and proceed from it as far as C, a very high mountain situated in the dark part, beyond the boundary. Since this mountain is of lofty height, it is therefore nonetheless lit by the Sun's rays even in the shadowy part, which would otherwise be impossible.

Now let the distance BC of the mountain from the boundary of light and darkness BAE be one twenty-sixth part of the whole diameter — as great, that is, as I say it can be at most, as the observations attest; in other words, let it amount to nineteen German miles, one of which makes four Italian miles. BA, the Moon's semidiameter, is 247 German miles, for the whole diameter BE was found in the preceding seventh chapter to be about 494 miles. These two

data, I say, suffice for my purpose; for the triangle to be solved is right-angled, and in it the two sides enclosing the right angle are known, namely BC, the greatest distance of the summit of some mountain from the illuminated part of the Moon, and BA, the Moon's semidiameter. If the hypotenuse is found from these, you will then have the height of the mountain itself. For if BA, that is AH, the Moon's radius, is subtracted from the hypotenuse AC, there will remain HC, the true height of the mountain. This hypotenuse AC, however, is found in various ways, as those skilled in geometry know. For example: 1. If the side

AB is squared, and likewise BC, and these two squares are added and the root is extracted: this is the hypotenuse sought. Or else, from the Table of Sines, the angle BAC is sought by means of those two sides; then, with the help of this angle and of one side, the hypotenuse AC — which is done without difficulty in the following way. By the first method, the square of BA, the Moon's semidiameter — which, as I said, is 247 miles, that is, 1976 eighth parts of one mile, or as many Italian half-miles — is 3,904,576. BC is 19 miles, or 152 eighth parts of one mile, and its square is 23,104. The sum of the squares comes to 3,927,680, whose square root is about 1982; and this at the same time is the hypotenuse AC sought, in eighth parts, that is, or Italian half-miles. The Moon's semidiameter BA, or AH, will be 1976 eighth parts. If, then, this is taken away from the whole hypotenuse, six will still remain — that is, six eighths of one mile, or three quarters of one German mile, or three Italian miles: and this is the true and genuine height of that mountain.

[Margin: Another way of computing the lunar mountains.]

Another way of computing the heights of the mountains is this. 1. The angle BAC is found in this way: as the Moon's semidiameter AB, 247 miles, is to the distance BC, 19 miles, so is the whole sine, 100,000, to the tangent of the angle BAC. When this has been duly carried out by the rule of three, the tangent comes out as 7692, so that the angle, from the Table of Tangents, is 4° 24′. With this angle found, I look up its secant in the Table of Secants, and it is found to be 100,296. I proceed, therefore: as the whole sine, 100,000, is to the secant of the angle BAC, 100,296, so is the Moon's semidiameter BA, 1976 — parts, that is, of such a kind that eight of them make one German mile, or four of them one Italian mile — to the whole hypotenuse AC in parts of the same kind; and so, once the calculation has been duly completed, 1982 results. If the Moon's semidiameter is subtracted from this hypotenuse, there will likewise remain six, that is six eighth parts, or three quarters, of one German mile. This height, then, the lunar mountains do not exceed, not even the highest of them all; although the Vene-

rable Galileo makes them equal to a whole German mile, or four Italian miles. This difference arises from no other ground than that he presupposes a distance of the illuminated point from the section of light and shadow [Sectio luminis & umbræ] greater than is right, as was seen from the foregoing.

[Margin: The greatest height of the lunar mountains.]

[Margin: A third, mechanical, method.]

Finally, a third way of investigating the lunar mountains is this. Construct a right-angled triangle on paper according to some definite scale: let AB equal the Moon's radius, 294, and BC the distance of the illuminated point. Then draw a straight line from C to A, namely the hypotenuse. That done, observe by means of that scale how great the difference between the hypotenuse and the Moon's semidiameter turns out to be; this difference is the height of the mountain sought. And although this work is done much more accurately by means of the first and second methods, I nevertheless thought it right to set out the method just indicated for the sake of those who are little accustomed to geometrical calculation.

Those mountains, however, whose summits are not lit any sooner than when they are at last one thirtieth part away from the line of light and shadow, that is, 16½ German miles — these, I say, are somewhat lower: about half a mile, namely, or a little more, according to the calculation indicated above. But those mountains in which this distance just mentioned is smaller still, namely only 1/34 part, that is 14½ German miles (and a great number of these is found), do not exceed 7/16 part of one German mile. Finally, if this distance is given as only 1/40 part, or 12½ miles, then the mountains barely exceed 5/16 part of one mile; that is, their height is found to be a little more than an Italian mile. In this way, moreover, the lunar valleys too can be measured, which near the boundary of the light are darkened on every side and very often extend a good way into the luminous part of the Moon, just as the mountains continually present themselves to view in the dark part of the Moon.

Here someone will perhaps think: "I should have supposed the lunar mountains to be much higher than I now understand them to be, since I am even fully persuaded that our terrestrial mountains are far loftier." But so that it may become clear to anyone

that the mountains of the Moon are not only similar to ours in height but even loftier, I shall therefore investigate the true height of the highest terrestrial mountains and, on so opportune an occasion, draw up a comparison between them and the lunar ones.

[Margin: Heights of various terrestrial mountains.]

[Margin: The opinion of the ancients on this matter.]

Now, although various mountains of the greatest height are found on the Earth's surface — mountains whose summits in some cases pierce the clouds, as is known to those who have visited such places and have either viewed them with their own eyes or measured them out on foot; among them are Mount Atlas, the Pyrenees, the Alps, Athos, Olympus, and so on — Theon nevertheless reports that Eratosthenes himself, with the aid of geometrical instruments, ascertained that the highest mountains of all do not exceed ten stades, measured, that is, along the perpendicular. This height does not yet equal a third part of one German mile, for 32 stades make only one mile of middling size, and 8 stades make one Italian mile, that is, 5000 feet. Likewise Pliny the Elder too

records, in book 2, chapter 65, that Dicaearchus the Sicilian, a pupil of Aristotle and a most distinguished geometer, also measured the highest mountains of various places at the expense of the kings of Egypt, and among others found Pelion, a mountain of Greece, to be the greatest of all; yet it was no higher than 1250 paces, or ten stades, as Eratosthenes had observed. Xenagoras, son of Eumelus, likewise found Olympus, after a careful investigation, to be of almost the same height: Plutarch testifies, in his *Aemilius Paulus*, fol. 479, that it is only ten stades and 96 Greek feet, or 100 Roman feet. There the same author went on to write to this effect: that geometers had established on sure grounds that neither are mountains higher nor the sea deeper than ten stades. Nor did Cleomedes determine the height of mountains, or of seas, to be greater than 15 stades along the perpendicular; this height is nearly equal to half a German mile. See on this subject the *Eratosthenes Batavus*, and in particular chapter 17. Similarly Geminus too reports, in his *Elements of Astronomy*, chapter 14 (in the *Uranologion* of Pétau, fol. 55), that the height of Cyllene, the highest mountain of Arcadia, was not yet 15 stades; and that of Satabyrius, or rather Atabyrius

mountain, situated on the island of Rhodes, was less even than fourteen stades along the perpendicular.

[Margin: What do the more recent writers think about the heights of terrestrial mountains?]

The more recent mathematicians of our own century agree with the ancients, holding it as certain that terrestrial mountains are lower still. This is clear from the *Sidereus Nuncius*, where Galileo discusses the heights of terrestrial mountains as follows: "On the Earth there are no mountains that come anywhere near the height of a single Italian mile along the perpendicular" — that is, a quarter of one German mile. To this Mario Bettini adds his own calculation, in *Apiaria* 8, Progymnasma 6, proposition 3; so does Giuseppe Biancani, and among others the most celebrated Denis Pétau as well, in the *Uranologion*, book 7, chapter 10, where he says: "Indeed, some of those most expert in geometry hold that the measure of the greatest height of mountains is a mile and a half, which is 12 stades" — or [?]/8 of one German mile.

[Margin: Some indeed assign an immense height to mountains, but without reason.]

Again, although some writers, ancient as well as modern, are found who ascribe an astonishing height to certain mountains — to the Caucasus and to Atlas, for instance, both of which they think rise almost as far as the Moon, and also to Mount Athos in Greece (today called Monte Santo) and to El Pico on the island of Tenerife in the Canaries — those same writers nevertheless contradict themselves in various ways in their descriptions, so that the impossibility of the thing is at once apparent. Willebrordus Snellius [Willebrord Snel] observed this very well in the *Eratosthenes Batavus* already mentioned, and so did Peter Crüger in his *Cupediae Astrosophicae*. For if it were possible for any mountain to exist that rose to a perpendicular height of only 6 German miles, its summit would certainly be seen from some place 100 miles away, as calculation confirms

— which is surely impossible and unheard of. Indeed, no mountain is seen even from a place 50 miles distant.

Let us grant that Mount Athos cast its shadow as far as the island of Lemnos, as Pliny reports (book 4, chapter 12), along with Solinus and others, from which they have sought to conclude that its height is remarkable. Yet Bellonius [Pierre Belon], who travelled through the whole region round about, writes that the crossing of Mount Athos, and that by the transverse route, takes no more than twelve hours. From this it is surely and plainly concluded that the mountain is not so lofty as

some indeed have reported. It therefore remains entirely true, as was established earlier and confirmed by the authority of the most distinguished philosophers, that our terrestrial mountains — those that hold first place among all the highest — do not exceed half a German mile, or two Italian miles, measured, that is, along a perpendicular line; and that only if any of so great a size are found anywhere at all.

[Margin: The difference between the mountains of the Moon and those of the Earth, and which are higher?]

From all this it at last becomes clearly apparent that the lunar mountains are certainly not of small but of altogether immense height — not only in proportion to the body of the Moon, which is 42 times smaller than the Earth, but they also far exceed the terrestrial mountains. For the lunar mountains rise to a height of three quarters of a German mile, or 3 Italian miles, as I have already mentioned and demonstrated by a correctly set-out calculation, whereas the terrestrial ones are raised scarcely half a mile along a perpendicular line.

[Margin: On the Moon, too, there are very great mountain ranges, just as there are here on the Earth.]

Moreover, there are also very great mountain ranges on the Moon in respect of length, which extend widely just as terrestrial mountains do: thus the lunar Taurus runs in an unbroken series for as much as 170 German miles; the Moon's Mons Sepher for as much as 150 German miles; the Moon's Apenninus for more than 100 German miles. It can therefore rightly be affirmed that very lofty mountains and very deep, very broad valleys exist on the Moon; let what has been said about them suffice for now. And so we at last bring the present chapter to a close and turn to the explanation of the phases themselves. On this occasion we have decided both to set out everything that bears on their true explanation and, for each phase individually, to raise and explain a number of diverse questions, pleasant and necessary, as the subject matter and our purpose require. Finally, in viewing the phases, I shall also elucidate more and more all those matters that seem hitherto not yet sufficiently explained and unravelled, but said only superficially, as it were. This, I believe, can now also be done much more accurately and easily, since the very best demonstration of all can be drawn from the visual examination of the figures appended.

CAPUT IX.

Chapter IX.

DE LUNAE PRIMAE AC NOVISSIMAE Phasi, nec non aliis nonnullis, quae circa hanc observationem, notatu digna occurrunt.

On the first and last phase of the Moon, and also on some other matters worth noting that arise in connection with this observation.

After the Moon has stayed hidden for some definite time and appears nowhere in the sky — not only because of its nearness to the Sun, but also because it turns the illuminated part of its hemisphere away from us — it at last comes about that it presents itself, most delightfully, to the view of us who inhabit the Earth. And hence it happens that the Moon appears after its conjunction sometimes sooner, sometimes later.

[Margin: The Moon was seen at once on the following day after conjunction.]

Indeed, while I was engaged in observing the intermenstrual Moon [intermestris Luna], it was seen by me at once, on the very first day after its conjunction with the Sun. I therefore judge that it will be worth my while to begin from that first phase and so to count all the others that follow, in order. For all those peoples who used a lunar year not only paid careful attention to this first appearance of the Moon, but also began the count and the start of every month from it, as is apparent from Geminus's book *Elements of Astronomy*, chapter 6, On Months, where he says: "It was the purpose of the ancients to reckon the months according to the Moon." And a little later: "The names of the days were given from the illuminations of the Moon."

[Margin: Many peoples began their months from the Moon's first sighting.]

[Margin: Although the Jews had their own lunar computation, they nevertheless carefully observed the first phase of the Moon in each month.]

This reckoning of months and days was adopted as a custom above all by the Jews, so that, although they had their own lunar computation, they nevertheless, led by the ancient custom of their forefathers, solemnly celebrated their feast days and new-moon festivals [Neomeniae] not from the true synod of the luminaries but from the first and last phase, that is, from the appearance of the Moon, when it is first perceived by sight in the sky after its conjunction with the Sun. How this observation was conducted, their rabbis, and the more recent chronologers drawing on them, relate at length. That the Moon's first rising, however, mostly occurs not on the first day after the interlunar period [interlunium] but only on the second, and often even on the third and fourth — this

is plain to all who observe the Moon. But whether this varying first appearance of the Moon — now later, now earlier — could have disturbed the

reckoning of the lunar year, both among the Jews and among other peoples who began that year from the first phase, or rising, of the Moon, and could easily have thrown their feast days into confusion, or not: that I leave to chronologers to consider and debate.

[Margin: What are the reasons why the new Moon cannot be seen at once, on the first day after the interlunar period?]

For our part, we shall only air this question about the first and last phase of the Moon, for the benefit of lovers of astronomy [Astrophili]: namely, why the Moon's first evening rising does not take place every month straight away, on the first day after its conjunction with the Sun; and whether it is possible to observe and see the first phase of the Moon when only a few hours have passed after the new moon.

Three causes in particular are given in astronomy that either delay or advance the first sighting of the Moon. The first is the obliquity of the sphere, which brings about long or short settings: for in the signs of long descensions, namely Pisces, Aries and Taurus, it can happen that the first phase of the Moon is seen shortly after conjunction. The second cause is the time of the Moon's conjunction with the Sun near the northern limit. The third, finally, is if the Moon is swift in motion, as it is near perigee. On the other hand, the first appearance of the Moon's phase can be delayed, so that the Moon is first seen in the evening only after some days have passed since the interlunar period. This happens if the conjunction falls in the signs of shorter descensions, such as Virgo, Libra and Scorpio, in which the new Moon lingers around the autumnal equinox; and if, moreover, the Moon has southern latitude, or is near the southern limit, and moves slowly at apogee.

Accordingly, when the three cases named earlier coincide around the synod of the Sun and Moon, it is entirely possible that the first phase of the Moon is noticed not only on the day following the new moon, but even on the evening of the very day on which the syzygy of the Sun and Moon occurs before noon — as Erasmus Reinhold demonstrated in his *Commentary on the Theorics of Purbachius* [Georg von Peuerbach], p. 155.

[Margin: When can the Moon be seen on the day of its conjunction?]

Indeed, it follows from the same principles that one may see the Moon [Greek: [[ἕ/ἓ]]ν[ην?] καὶ νέαν (hen[ēn?] kai nean, "old [?] and new")] — last and first — on one day, especially around springtime, when the twilights are shorter, since these can contribute not a little to this appearance of the Moon. But if

the causes already mentioned that hasten the Moon's rising do not always work together, and only one of them is lacking, then this first phase finally presents itself on the day after the interlunar period; but when two of the requisites are wanting, it can happen that the first phase of the Moon comes into view only on the third day. And when all three of the conditions that accelerate the Moon's rising are lacking — so that the Moon is in the signs of shorter descensions, at the southern limit, and at apogee — then this first

appearance of the Moon occurs only on the fourth day after its conjunction with the Sun. I shall demonstrate and explain the variety I have indicated, not only in the present phase but presently in a great many others as well.

[Margin: When is the first Moon seen on the second, third or fourth day?]

Theon of Alexandria, Alfraganus [al-Farghānī], al-Battānī and Māshā'allāh do indeed hold it to have been found, by the assiduous and long-continued observations of the ancients, that the new Moon can be seen once 12 time-degrees of the equator have elapsed from conjunction — that is, four-fifths of one hour. But I believe these ancient astronomers are plainly mistaken here. For the causes I touched on earlier that retard the Moon's rising can concur in such numbers that the rising scarcely sets in before the third or fourth day after the interlunar period.

[Margin: The error of the ancient astronomers concerning the Moon's first rising.]

Indeed, even if all three of the causes just named that promote an earlier appearance of the Moon do sometimes coincide, I nevertheless doubt whether the last and the first Moon can be seen on one and the same day — especially in these northern places, where the elevation of the pole is more northerly and where lofty mountain peaks for catching the first sighting of the Moon are lacking — just as there are, besides, only the rarest examples of the last and the first phase of the Moon seen on the same day on a level horizon.

[Margin: Very rare examples are found of the last and the first Moon seen on the day of the synod.]

The ancient astronomers did indeed record examples of this kind, and when they occurred they called the day, on that account, [Greek: [[ἔ/έ]]ν[ην?] καὶ νέαν] "old and new". Likewise Francesco Patrizi, in book 20 of the *Pancosmia*, p. 114, reports a very similar example concerning Vespucius [Amerigo Vespucci], who observed the old and the new Moon on one and the same day — but, as Patrizi adds, beyond the equinoctial line. And there he appends these words: "This, however, does not seem to have been able to happen otherwise than in air much freer of vapours than it is with us." I too gladly grant this, and believe it to be true.

[Margin: Vespucius saw the old and the new Moon on one day, beyond the equinoctial line.]

As for the first phase of the Moon that I observed — on the day immediately following the synod of the luminaries, namely on 1644 April 8, new style, a Friday [feriâ 6.], the synod having taken place the day before, not in the evening but in the morning, at about four — an observation of this kind is a rare occurrence in our locality, as those who have devoted themselves to the task of observing it know. For the new Moon is very seldom seen before the third day after conjunction.

[Margin: Observation of the Moon's first phase immediately after the day of the interlunar period, 1644 April 8, new style.]

That this first phase was seen so soon, shortly after conjunction, came about because two of the conditions already mentioned — causes of a swifter appearance of the Moon — were present here. For in the first place, the time of the spring conjunction fell at or about the 18th degree of Aries, and at the time of its appearance the Moon stood in the 13th degree of Taurus: that is, in the signs of long descensions, and indeed, after Pisces, in the principal ones, namely Aries and Taurus. Then, too, the Moon was swift, being near perigee. Hence it came about that the Moon was seen when 40 hours had passed after its true conjunction — and, indeed, still fairly well elevated above the horizon.

[Margin: Why was the first Moon seen so soon at the time just mentioned?]

Indeed, even had it been three or four degrees nearer the Sun, it would nonetheless have been seen; that is, even if the true conjunction had occurred on the previous day not before noon but after it, this first phase would have appeared on the following day. Moreover, if the Moon at that time had stood not near the southern limit (for its latitude was about 4½° south) but near the northern limit, the first phase of the Moon could have been seen within 24 hours after its conjunction with the Sun.

These three requisites, however — that the Moon be in the signs of long descensions, at perigee, and at the northern limit, at the time, that is, of conjunction or of appearance — very rarely concur together (as has already been said). For now one, now another is wanting, and this delays and hinders the Moon's appearance, so that it cannot be seen on the first day after the interlunar period, even if at that time (which is not impossible) the sky is clear and the observer's diligence is not lacking.

[Margin: The three conditions for a swifter appearance of the Moon very rarely concur.]

Indeed, within a span of nine years these three requisites will scarcely set in together, even if every new moon is examined — except around the year of Christ 1654, in the months of April and May, when the Moon's

[Margin: In 1654, in the months of April and May, the first phase of the Moon will set in earlier.]

Diagram. A full-page engraved plate. Beneath an engraved caption in script, the whole disc of the Moon is drawn as a circle in outline; only a thin crescent along the right-hand and lower right-hand limb is lit, and it is speckled with small spots and shadings. A single engraved character stands at lower left, and the engraver's signature at lower right.

Caption: "The First and Newest Phase of the Moon. Observed in the 13th degree of Taurus, near perigee and the A. limit[11]. At Danzig. In the year of Christ 1644, on 8 April, at hour 8 counted from noon, but counted from the conjunction, in hour 16 of day 2." [Hevelius counts the day in progress: hour 16 of day 2 means 1 day and 16 hours after the conjunction]

[11] *Limit. A.*, an abbreviation not expanded on the plate

- Lower left: 1 (a single engraved character: the plate number, in the J-form figure 1)
- Lower right: "Autor Sculps." — engraved by the author.

Blank verso of the plate leaf, with the plate and a page of type showing through in mirror image.

first phase will be visible fairly soon — indeed on the very day after its conjunction with the Sun — provided the sky shines clear.

Two requisites, to be sure, can more often concur together at the Moon's conjunction, as also happened in the observation already presented: namely, that the Moon is in the ascending signs [ſignis Aſcendentibus] and at perigee, or else near the northern limit and in the ascending signs. Then the Moon is seen raised above the horizon earlier, once 24 hours, or even more, have passed, according to when the synod of the luminaries falls — although this too happens rather rarely, and certainly not every year. It could happen, however, in the year 1646 around the vernal equinox, if the air is clear then; and in the year 1652, too, in the months of March and April, the first phase of the Moon will come about earlier. For two requisites are found to be present at the time when the Moon is between months [tempore intermeſtris Lunæ], as also happened here. But in the preceding years the conjunction of the Moon and the Sun will not take place near perigee, nor near the northern limit, even if it falls in the ascending signs — which must happen every year.

[Margin: Why will it be granted to see the Moon's first phase sooner in the years 1646 and 1652, around and after the vernal equinox?]

From this it can be gathered that a phase of the kind observed here is rather rare to see. For even when it happens that two requisites are present, a clear evening is still not always granted, and so the view of the Moon is hindered by intervening clouds, as I have often experienced.

In order that what I have set out about the causes of the swifter and the slower first appearance, or kindling of the light, of the Moon may be the more firmly established, I shall therefore bring forward here various observations, made at times when, with a clear sky, I did look for this first phase of the Moon immediately on the day following its conjunction with the Sun — but, with a single exception, have so far not yet been able to perceive it. For from them the causes that at other times delayed the swifter first rising of the Moon will be clear enough. Indeed, from 1644 April 8, the day on which I saw the Moon's first phase on the very next day after conjunction, I repeatedly raised watchful eyes and was roused to look at the sky, to see whether at another time too I might make out the face of the newest Moon on the day after the new moon [altero poſt Neomeniam die]. And with what success? Listen: first, on 1644 June 5,

I could not make out the Moon's horn in the evening. It was indeed in Gemini, but besides that it was at the southern limit and was lingering beyond perigee. Likewise, on July 5 of the same year, I could not catch the Moon's first phase on the day after conjunction. Nor is that surprising, for not one of

the requisites for an earlier appearance of the Moon was present at all. Nor, therefore, was it possible on the following day, July 6, to see the Moon's first horns, so that it was not until the third day after the synod — namely on July 7 — that I then managed to see the new Moon, and that very close to the western horizon. Moreover, at the other intermenstrual Moons of this year I went looking for the first phase on the following day in vain (as anyone not unskilled in celestial reckonings easily understands), because the conjunction of the luminaries now fell in the signs of shorter descensions.

[Margin: Why was it not possible to see the Moon on the day following its conjunction?]

Similarly, on 1645 March 28, a Tuesday [feriâ 3], when 23 hours had elapsed after the synod of the luminaries, I searched carefully for the new Moon in the evening, but it was not found. For only a single requisite was present, namely the Moon's motion in Aries, a sign of long descensions; against that, the Moon had a southern latitude of more than four degrees, and on top of this it was moving at apogee [Apogæa], that is, at its farthest from the Earth. But had those two impediments not stood in the way, I could certainly have perceived the phase itself conveniently by sight at this time too.

[Margin: Another fruitless observation.]

In 1645, on April 27, a Thursday [feriâ 5], I again applied myself, at eight o'clock in the evening, to observing the Moon's first appearance, and this time it did not disappoint my hope. For straight away, on the day after conjunction, I caught it in the form in which it is seen depicted here, and in which it was observed the previous year. The cause of this earlier rising is twofold. The one, that the Moon was in Taurus, a sign of long descensions; the other, that it was at perigee. There is this as well: the true conjunction of the Sun and Moon fell quite early in the morning of April 26, so that by the time it was seen by me 42 hours had already passed since the synod of the luminaries. Yet it could not have happened sooner, for the Moon was placed at its greatest southern latitude.

[Margin: Observation of the Moon's first phase on the day after the conjunction of the Sun and Moon.]

By way of conclusion I shall point out one thing more, relying on the foundations

of the present phase of the Moon, concerning the mountains of the Moon, which were also mentioned above in Chapter 6. For at definite times these become plainly visible even on the very periphery of the Moon, so that the Peripatetics may at last understand both the force of our demonstrations, by which we defend a serious matter, and, on the other side, the weakness of their own arguments, by which they attack our opinion.

First, none of the Peripatetics who has merely seen such a nascent, first phase of the Moon will deny that the boundary of light and shadow is irregular, rough and uneven. Next, it is abundantly clear from Chapter 7 above that the space lying between that notable spot of the Moon near the periphery, not far

from its western limb (which, for the sake of better understanding, we call the Palus Mæotis [Paludem Mæotidem]), and the outermost edge is, because of the motion of libration, sometimes wider and sometimes also narrower.

[Margin: On the mountains of the Moon at its periphery, and on the cause of the space there being now narrower, now wider.]

That space is widest of all when the Moon (as was also said before) is in the sign of Cancer, and indeed near the southern limit; and it is narrowest when the Moon is in Capricorn near the northern limit. There is thus a quite evident difference between the greatest and the least libration of the Moon, namely 1/36 of the whole diameter of the Moon, as can be gathered from the motion of the Moon's centre.

[Margin: The difference between the greatest and the least libration of the Moon is 1/36 of the whole diameter of the Moon.]

Moreover, since this phase of the Moon shown here occurred not far from the summer solstitial sign, namely the beginning of Cancer — that is, in the 13th degree of Taurus — near the southern limit, it follows that the space between the periphery and the Palus Mæotis was then also very nearly at its widest. This phase, at its middle, where it is seen most divergent, is reckoned at one thirty-sixth part of the Moon. From this it appears that in this figure the boundary of light and shadow does not yet reach the point at which, at other times, when the Moon is in Capricorn near the northern limit, the periphery must be bounded; and that this phase was therefore perceptibly narrower, as the proportion mentioned before indicates quite plainly. And even if we grant that this phase of the Moon was then as wide as is the greatest and least libration between the Palus already mentioned and the periphery, with the Moon standing in Cancer, nevertheless from this

too it follows that at that very time this boundary was also in the place where, at other times, the true and genuine periphery of the Moon was seen when the Moon was in Capricorn.

Therefore, since these things really are so — as anyone equipped with a good tube who examines this phase properly will not deny — it follows by irrefutable reasoning that on the periphery too, which at times, and indeed for the most part, appears even and smooth, there are great and high mountains and deep valleys, just as in the other parts of the Moon. It follows, too, that on its averted half the Moon is just as dense, rough and humped as it is in the visible hemisphere, as is plainly detected from the section of light and shadow, as was said before; and, moreover, that the mountains around the periphery are, if not higher, certainly not lower than those noticed around the half Moon at the time of quadrature. The distance of the illuminated summits of the mountains does not, indeed, appear as great here as was determined towards the end of the preceding chapter. But what do you suppose is the cause of this? Nothing else, of course, than that this section, being close to the periphery, is viewed by us more obliquely than the others, which lie nearer the centre. And yet it is a matter for wonder that, on account of the Moon's wonderfully round

form, this boundary should still appear so rough. For none of the Peripatetics will doubt that this rough and uneven face and surface of the Moon really is so — and he will doubt it the less, the better the optical tube with which he has carefully contemplated such phases.

[Margin: A manifest argument for mountains at the periphery.]

CAPUT X.

Chapter X.

DE LUNAE CORNICULATAE CRESCENTIS PHASI.

On the phase of the horn-shaped, waxing Moon.

What I think I sufficiently said in the preceding chapter about the nascent and first Moon, and also about the causes of its later appearance, may in its own way be affirmed of the phase of the horn-shaped Moon as well.

[Margin: What the horn-shaped Moon is.]

We call horn-shaped [corniculata] the phase which for some of the ancients is the second Moon, because it is seen at the very earliest on the second day after the synod of the luminaries, and follows the first Moon.

[Margin: Causes of the earlier and the later appearance of the horn-shaped Moon.]

That it cannot always be perceived by sight on the second day, however, can be caused by all the same things that do not allow the first Moon to be seen on the first day after conjunction. The chief cause, though, is when the Moon is in the signs of short descensions [Signa brevium descensionum], such as Cancer, Leo, Virgo, Libra, Scorpio and Sagittarius. For even if the Moon is in perigee and near the northern limit, yet if a sign of long descensions is not added, the horn-shaped Moon is awaited on the second day in vain. 1644 October 2 can serve us as an example: on that day the horn-shaped Moon could by no means be seen on the second day after conjunction, because it was in a sign of short descensions, near the beginning of Scorpio, and at the same time in apogee; and although it had a great northern latitude, yet, since the primary requisite was lacking, it appeared nowhere in the sky at that time. There is no need to illustrate the matter with more examples, since it is plain in itself and is to be understood in no other way than this: the first and second phase of the Moon, on the first and second day after the new moon is completed, is sought in vain — especially in the evening, a little after sunset — unless the three requisites listed in the preceding chapter were present at the time of the conjunction or of the Moon's appearance.

But on a day that is not overcast, with the Sun shining very brightly, it is not impossible to see this second Moon on the second day after conjunction, even though no requisite is given; and this can be done either with a respectable optical tube, or with the sight of the eyes alone,

vigorous and unimpaired — just as I myself have seen the Moon in this way on separate occasions, and have also shown it to others.

[Margin: The second, or horn-shaped, Moon seen with the Sun present.]

For in 1644, on July 6, I was well able to see the second, or horn-shaped, Moon in the afternoon hours, with the light of the Sun shining clearly upon it; and yet on the following evening, after sunset, there was still no opportunity of seeing it — to pass over other examples.

[Margin: That the phases of the horn-shaped Moon, and those fresh from conjunction, can be detected sooner on a bright day than at night.]

From the cases adduced one may judge quite clearly that often — indeed almost always — phases of this kind are not incapable of being seen better on bright days than in the evening after sunset. This difference, however, remains between the Moon first seen by day and by night: the phases of the Moon seen by day, whether with clear sight or with an optical tube, we cannot draw so accurately, because, namely, of the greater light standing around it and the nearness of the Sun, which renders the lesser light of the Moon somewhat dimmer. For here too the well-worn saying applies: *The greater light obscures the lesser.*

[Margin: Why it is likely that the newest phase of the Moon can be seen better by day, on the day of conjunction, than at night.]

Hence it seems to me entirely likely that even the first and newest phase of the Moon can be noted by a most diligent observer of sharp sight sooner, and more often, by day than by night. Indeed, I think that the old, or last, Moon and the first Moon can be noticed on one and the same day, even in these northern regions. Let the glare of the Sun deter no one from watching out for every opportunity; for in this way he can be safe from harm to his sight, if he uses the two coloured glasses I mentioned above in chapter 2, or rather an excellent helioscope, through which one may look at the Sun itself safely, without injury to the eyes, as I showed in the place already mentioned. This observation can be undertaken above all when the conjunction of the Sun and Moon falls around noon. For I have no doubt that it is possible to see the old Moon before noon and the new Moon before sunset, unless thick vapours of the air have stood in the way. Since in a cloudless sky all the phases of Venus, however very close to the Sun, can be discerned with a telescope — and I adduced observations of this kind in chapter IV — there will surely also be the opportunity of seeing the Moon, which appears far larger than Venus. And even if we grant that such a phase is very narrow, it can by no means be more slender than the horn-shaped face of Venus.

Diagram. A full-page engraved plate. Beneath an engraved caption in script, the whole disc of the Moon is drawn as a circle in outline; a crescent is lit along the right-hand limb, running from the upper right round to the bottom of the disc, and is marked with crater-like rings, a dark patch on the right-hand limb, and hatched shading. No letters stand on the disc. An engraved numeral stands at lower left, and the engraver's signature at lower right.

Caption: "Phase of the Horn-shaped Waxing Moon. Observed in the 14th degree of Aries, near the southern limit and apogee. At Danzig. In the year of Christ 1645, February 28, at hour 7 counted from noon, but counted from the conjunction, in hour 9 of day 3."

- Lower left: "2." — the plate's number.
- Lower right: "Autor Sculp[?]it." — engraved by the author.

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Moreover, to the Moon's primary light is added also the secondary light, which at the time of full moon, beyond the rest of the body, is usually very bright and very great — as will be discussed more fully in chapter 12. With the help of both, therefore, the Moon can be detected all the sooner. But this would succeed best of all for an observer of the old and the new Moon if he took himself up onto the ridge of a fairly high mountain, where he would be placed outside the lower region of the air, which intercepts the Sun's rays very greatly and somewhat obscures our eyes. Indeed Kepler too, in *Astronomiae Pars Optica*, chapter 6, section 11, writes that nothing prevents the Moon from being seen at the very moment of conjunction, next to the Sun in mid-heaven, when it is traversing the other limit.

[Margin: The Moon can be seen next to the Sun in mid-heaven.]

Now I shall come to the image of the horn-shaped phase itself, and point out what is worth noting about it. In the earlier phase great roughness was indeed detected, both in the illuminated part and in the section of the shadow; yet it was not yet possible to see any well-known spot, mountains or seas, since the luminous part was very thin and, moreover, very close to the Moon's limb. In this later observation of the second Moon, however, several mountains that are not unknown could already be seen, casting a fairly blackish shadow into the valleys around the western side of the mountains: such as Mons Nerosus, Insula major Caspii, Montes Hippoci, Mons Sanctus, Montes Alani, M. Alauni and others.

[Margin: Some notable points about the phase of the horn-shaped Moon.]

Among other things, this too presents itself here as worthy of some consideration: the Montes Alani, which surround Palus Mæotis, are not the lowest of the remaining mountains, but fairly high. This is gathered from the fact that their summits stood out conspicuously in the illuminated part of the Moon, even though at that time they were not yet far from the periphery. Next, it is also notable that so even a segment crosses Palus Mæotis; from this at least some correspondence can certainly be established between that part and our waters in respect of their matter, if they are not really to be natural waters, because the horizon there (which represents the boundary of light and shadow) is seen to be smooth and even. In addition, we must record that the Marsh already mentioned so often, when it first came into view,

[Margin: The Montes Alani are very high.]

was of so weak a colour that in the following phases it became darker and tended more and more towards blackness. The reason for this change has

already been touched on several times and attributed to the obliquity of the line of sight. The black spots that push in on the western side of the Marsh I judge to be shadows cast by, and issuing from, the various lofty Montes Alani which surround the Maeotis. That the shadow does not hold together, however, may perhaps have this cause: either that one mountain slopes more steeply than another, or that each has its own distinct space.

[Margin: A probable reason for the shadow on the Moon not holding together.]

Now, those three small bright points on the lower horn of the Moon, almost on the periphery itself, are without doubt certain particular summits of higher mountains, conspicuous above all the rest; they are evidence that there are quite remarkable mountains on the very circumference of the Moon. Finally, the space between Palus Mæotis and the periphery must also be considered as regards its breadth; for, as was said above, it becomes either wider or narrower every day, in accordance, that is, with the motion of the Moon's libration. Since, therefore, this phase of the Moon in the 14th degree of Aries has a southern latitude of almost four degrees, this space is so disposed that from it one may estimate the lesser western lake. In the other, subsequent phases we found that space far otherwise disposed, as the phases themselves, once seen with the eyes, will clearly show.

[Margin: On the libration of this phase.]

CAPUT XI.

Chapter 11.

DE LUNAE FALCATAE CRESCENTIS PHASI.

On the Phase of the Sickle-shaped Waxing Moon.

That the horns or cusps of the rising and new Moon, or of the old and waning Moon, are sharper or blunter at one time than at another is known even to the common people, so much so that country folk gather and foretell from the shape of the Moon's horns the state of the air for the following day. For when the horns are well pointed, they promise themselves good, clear weather; but if, on the contrary, they are very blunt, then

[Margin: A prediction of the future state of the air from the shape of the Moon's horns: on what foundation does it rest?]

they foretell a cloudy, turbulent, windy sky, and rain; and this omen is scarcely so very unreliable and uncertain. For when we see the horns of the Moon blunt, they indicate air full of thicker vapours and humours. Otherwise the same horns of the Moon, at the same age of the Moon, equally illuminated and with the air clear, are equally sharp, with the naked eye as judge. When examined through a good optical tube, however, those horns appear much purer, finer and sharper, just as they also really are; for the telescope strips away

the superfluous and adventitious rays that widen the cusps of the Moon more and more and make them blunter.

[Margin: The telescope removes adventitious rays from the Moon.]

And it does this not only at the horns but also in all the remaining illuminated parts of the waxing or waning Moon. For those phases always — even when the air shines at its very clearest — appear larger and broader to the naked eye than they really are and than the spyglass shows them; indeed, according as one phase is younger or older than another, so too that borrowed light is seen as broader or narrower relative to the Moon's proper and genuine light. And as much as all the phases curved into horns grow and increase after the new Moon, so much does this augmentation of light diminish from day to day in a fixed proportion; the contrary, however, happens in the sickle-shaped and horn-shaped phases of the waning Moon. For the more those phases diminish daily, and the more contracted the illuminated part becomes, the more this borrowed augmentation of light grows.

[Margin: As the phases grow with the waxing Moon, so the augmentation of the phases' light decreases.]

From many long-continued observations, moreover, I have found that the phase which appeared on the third day after conjunction (when the Moon was seen on the first day after its coitus), and likewise before conjunction, when it is seen with the interlunar period still one day ahead, appears almost half as large again when perceived with the naked eye as when examined through the viewing tube. The second phase of the Moon, which occurs on the second day after conjunction, looks twice as large without the optical tube as with it, and the first, nascent phase almost three times broader than it really is, though in itself it is quite narrow. All of this will perhaps seem very remarkable to the reader.

[Margin: Why do the younger phases of the Moon, viewed by the naked eye alone, appear larger than through the optical tube?]

This difference in appearance, however, nothing but the adventitious rays and the surrounding light, which widens that other light more and more

and displays it to our sight, bring about. How this happens, and what the reason for it is, will be set out briefly in what follows.

First of all, this arises partly from an illusion of sight, partly from our rather thick air, which immediately surrounds the Moon. For we can clearly detect that both happen when the Moon is still passing near a tower, a wall or a chimney, and the air around the Moon is seen to be pure and clear on every side: there, the nearer the air is to the Moon, the brighter it is, and the older the Moon becomes, the less this light appears, until at last it dies away. Hence it comes about that the limbs, of the Moon as much as of the air, are as it were confused on the retina of the eye, because of the excessive opposition of light and darkness. When, however, we look at the Moon through a small hole, especially at twilight, or — which is better — through an optical tube, that light cannot fall so strongly and copiously into the opening of the pupil;

consequently it neither makes so strong an impression on our eyes nor spreads itself so much.

From this the cause is also seen why eclipses of the Sun, observed with the naked eye, or through a small hole without convex or coloured glasses, or without an optical tube, always appear smaller than they really are. According, moreover, as the air is purer or less pure, so this light of the Moon appears smaller or larger to our eyes.

[Margin: Why do eclipses of the Sun, viewed in a darkened chamber through a hole with the naked eyes, always turn out smaller than they really are?]

And this air itself is also so powerful and strong at spreading light in our eyes that even the edges of some dark body appear very white and as it were transparent, as always becomes evident in any black body set against bright air. This is especially so if in the evening you set up some stick, placed obliquely, at some distance in front of a lighted candle: you will then notice that on the side facing the light of the lamp the stick appears far thinner, as though it were translucent and hollowed out along its upper and lower edges. For it is the nature of light to diffuse and enlarge itself in every direction. While this happens, therefore, it necessarily follows that continuous opaque bodies are somewhat altered and cut into.

That the smallest phase of the Moon, however, seems to spread itself most of all, beyond the other, older phases, has without doubt this cause: in such a phase the light is, as it were, more compressed.

[Margin: Why does the first phase of the Moon spread itself most of all?]

Diagram. A full-page engraved plate. Beneath an engraved caption in script, the whole disc of the Moon is drawn as a circle in outline; a crescent is lit along the right-hand limb, running from the upper right round the bottom of the disc towards the lower left. It is marked with crater-like rings, a large dark hatched oval on the right-hand limb with a smaller hatched patch above it, and a long hatched dark band along the lower right; a row of small bright points stands on the outline beyond the lower-left end of the crescent. No letters stand on the disc. An engraved numeral stands at lower left, and the engraver's signature at lower right.

Caption: "Phase of the Sickle-shaped Waxing Moon. Observed in the 1st degree of Pisces, near perigee [?] and the descending node. At Danzig. In the year of Christ 1644, January 12, at hour 5 counted from noon, but counted from the conjunction, in hour 20 of day 3."

- Lower left: "3" — the plate's number.
- Lower right: the engraver's signature — engraved by the author.

Blank back of plate 3; the plate shows through in mirror image.

And the more the light is constricted, the stronger the impression and confusion it produces in our eyes, and the more it seems to spread out. For it is an axiom of optics: *compressed light is stronger than dispersed light.* Indeed, the same thing is found not only in the phases of the Moon but also in the sickle-shaped and horn-shaped phases of Venus, whose case is almost the same. For

the smaller and narrower her phases become, the more they seem, in proportion, to spread themselves out — always, however, much more before twilight than in twilight, but less after sunrise than in twilight, as I also mentioned above in Chapter IV.

[Margin: Why do the phases of the Moon, curved into horns, appear larger than usual?]

From what has just been briefly set out, the cause can also in some measure be gathered why the phases of the Moon curved into horns, waxing as well as waning, appear larger in diameter and seem to exceed the part that is not illuminated. (At that time this dark part is quite visible, because of the secondary light reflected from the Earth.) They do so to such an extent that someone relying on the testimony of his eyes alone would dare to confirm on oath that the unilluminated hemisphere is far smaller than the illuminated one. But this arises from no other principle than from adventitious rays, as the optical tube clearly proves: for when a phase is examined through it, none appears larger or smaller than it ought to be in relation to the unilluminated part of the Moon.

[Margin: Useful notes on the sickle-shaped phase of the Moon.]

Concerning this present sickle-shaped phase, moreover, the following points can still be noted towards the end of this chapter.

I. First, that the form, shape and colour of the Palus Mæotis [Paludis Mæotidis] differ somewhat from those in the following phase: for here the shape is narrower and the colour paler. So too the Montes Riphæi here appear narrower and more compressed than in the following figure. The reason can be sought from the eighth chapter, from which it is seen that this arises chiefly from the motion of libration: for since the mountains, together with the marsh, are here nearer the periphery than in the other figure that follows shortly, no other appearances can arise.

II. Next, four certain notable things are present and are seen here, round and very bright, like little heads of nails, in the

lower edge of the Moon, or in its lowest horn; but these are commonly always seen in such a phase of the Moon.

III. Finally, from the brightly lit summit of lofty mountains — here, namely, that of Mons Paropamisus [Montis Paropamiſi] — it is gathered by infallible reasoning that there are just as many very high mountains of this kind near the edges of the Moon as around its centre. For this observation makes it plain that the distance of the summits in these Montes Paropamisi from the boundary of light equals about one fortieth part of the Moon's diameter.

CAPUT XII.

Chapter 12.

DE LUNAE CORNIGENAE CRESCENTIS PHASI.

On the Phase of the Cornigenæ *Waxing Moon.*

[Margin: The Moon is not only an opaque body, but also uneven, rough and dense.]

That the Moon is an opaque body — indeed a most opaque one — and that it receives all its light solely on loan from the Sun and transmits it to us on the Earth by reflected rays, no one among the learned will deny any longer; and we have demonstrated it with the strongest arguments in the sixth chapter of the *Selenographia*. From this it also follows that the globular body of the Moon is by no means even on all sides, smooth and polished, but uneven, rough and hard: for in this way the reflection of the Sun's rays on the Moon can be the more powerful. Hence it also comes about that our Earth — which is no less a most opaque body, and thoroughly rough, uneven, raised and sunken — is not unable, at certain times, to project the light it has received from the Sun by reflected rays as far as the sphere of the Moon; and this light is the nobler, greater and stronger, the greater the Earth is than the Moon.

[Margin: The source from which that dim and secondary light arises before and after the interlunar period.]

By this reflection of the solar rays from the globe of the Earth a dim, secondary light is produced. It is always seen a little before or after the conjunction of the Sun and Moon in the greater, remaining part of the Moon, the part that is not illuminated — that is, when one attends to the brightly lit horns and to the boundary of light. For about this secondary light of the Moon there have so far been various opinions. Some hold that it is implanted, inborn and

natural — a small light belonging to the Moon, detected not only around this time but also at the time of lunar eclipses. Others contend that it is a reflection from the aether. There are those who say that the Moon is a semi-transparent body, and that hence, at the time of conjunction, when the Sun lights the Moon from behind — that is, with respect to us — the Sun's light partly penetrates it and shines through; and that this is why that light is weaker.

But that none of these opinions yet expresses the true cause was shown a little earlier, in the sixth chapter, with many arguments. For the sake of brevity, therefore, I shall dwell no longer on the refutation; instead I shall go on to confirm and explain the true view, and set out further the genuine cause of the secondary light and whatever here deserves notice. First, then, it must be understood that in the phases of the Moon curved into horns this secondary light is the stronger, brighter and more evident, the smaller and narrower the phase is, and the nearer to the conjunction of the Sun and Moon itself.

[Margin: The more the Moon grows from day to day, the more the secondary light decreases in brightness.]

For the greater the increase the Moon takes on each day, and the fuller the phases themselves become, the smaller, weaker and dimmer this light grows from day to day, until at last, at the time of the first quadrature, it vanishes entirely and can no longer be made out even by a man of the keenest sight. I remember, however, that with the help of a skilfully made optical tube I saw that secondary light even on the day after the Moon's first quadrature, and

could make out its whole disc, and not dimly. The waning Moon also keeps the same proportion. For soon after the last quadrature this small secondary light first shows itself; from then on it grows more and more, and becomes more evident and stronger every day, so that this small light can be seen from the last quadrature right up to the first. But from the first quadrature to the last, and in the phases swollen out on both sides, this light cannot be perceived either with the telescope or with the naked eye.

[Margin: The true cause of the secondary light in the Moon before and after its synod with the Sun.]

It is therefore not without reason asked here what the cause may be why, shortly after or before the conjunction of the Sun and Moon, this secondary light is so strong and most clearly visible. To resolve this question the following principle must be laid down: our

Earth, namely, has the very closest kinship with the Moon (as will also be said at greater length below); and this kinship — to say nothing now of the rest — consists also in this: that each communicates the Sun's light to the other by reflection, not indeed at one time, but at different and distinct turns. As far as the Moon is concerned, by night, after the setting and departure of the Sun, it carries its borrowed light to us by reflected rays, and with its weak light it strives to make up in some measure for the Sun's absence, above all at the time of full moon — just as it was also created by GOD for this service, to rule the night. The Earth, therefore, wishes as it were to repay the Moon the thanks it owes by a service in return, when it in turn casts some of the Sun's light onto the Moon by reflection. It does so not, indeed, at the time of full moon, when the Moon is most strongly lit by the Sun, and something like midday is observed on it (especially by those who dwell, with respect to us, about the middle between the Pontus Euxinus and the Mare Mediterraneum), and it needs no greater light; but at the time when the Sun begins to lean towards its setting, and the hemisphere of the Moon that faces us and is visible to us can no longer be lit by the Sun, now setting, and night is at hand — which happens at the time of the interlunar period.

[Margin: The Moon's Full Earth.]

For then the Earth transmits the Sun's light to the Moon by reflection most powerfully, so that at that time there is a Full Earth [Pleniterrium] on the Moon. This can happen most conveniently at that time. For at full moon the Earth stands interposed in a straight line between the Sun and the Moon, so that the Moon, with its half opposed to the Sun and illuminated, also faces the Earth. Then, however, the Earth is lit on one side, though not on the side that faces the Moon: for that side then lies hidden, wholly wrapped in darkness, so that the Earth, with respect to the Moon, is dark and murky, and on the Moon there is a conjunction of the Sun, or New Earth [Noviterrium].

[Margin: The Moon's New Earth.]

But when the Moon, with respect to us, is in conjunction with the Sun, then, with respect to the Moon's exposed hemisphere, our Earth stands opposite to it,

and the upper hemisphere, turned towards the Moon, is wholly illuminated; by contrast, the lower hemisphere of the Moon, which faces the Earth, is quite dark, because it is in conjunction with the Sun. In this way, however, the hemisphere of the Earth can impart this light to the Moon effectively and clearly enough — namely by direct rays, since these globular bodies incline towards each other in a straight line.

[Margin: Why does this secondary light of the Moon at last vanish entirely after the first quadrature, and return after the last quadrature?]

But as the Moon, because of its swift motion, recedes more and more each day from the straight line of the Sun and the Earth, the Full Earth then decreases in that proportion and the phases become narrower, so that, as time goes on, so large a portion of the illuminated Earth can no longer be seen from the Moon; and hence from day to day thereafter the Earth transmits a weaker light to the Moon. And this light fails all the more each day, and grows dimmer, because every day the Earth casts the Sun's rays onto the Moon more obliquely, owing to its greater distance from the Sun. And this is the reason why, at the time of the first quadrature, this secondary light of the Moon, reflected from the Earth, becomes less visible because of the fewer and more oblique rays, and at last withdraws from view altogether; whereas, by contrast, about and after the last quadrature it first shows itself to be seen.

[Margin: It is shown graphically.]

But so that what has been said so far may become the clearer, consider, reader, I beg you, the figure appended, in which are shown not only the illuminations and phases of the Moon with respect to us, but also the illuminations and phases of the Earth with respect to the Moon, as well as the secondary light of the Moon that proceeds from each particular phase. In this figure A is the Sun, B the Earth, and C, K, D, E, F, G, H, I the Moon. The darker lines, drawn to the Sun with respect to the Moon's position, are the lines of illumination [lineæ illuminationis]. Whatever lies between these and is turned towards the Sun — that segment can also be lit by the Sun. The rest, however, which is shaded, as it were, with lines either single or double, the Sun cannot light, and so it remains dark.

[Margin: The lines of vision and of darkening in the Moon: how do they run from the Sun and the Earth?]

The other lines, marked with dots, which run from the Earth B, as the illuminated part, to the unilluminated part of the Moon, are the lines of vision [lineæ viſionis]. And whatever part of the Earth's portion lies between these represents the size of the Earth's phase; whatever faces the Moon, however — such as the segment marked with single shading lines — shows the small part of it on which the Sun's rays reflected from the Earth fall.

[Margin: The Full Earth on the Moon — but when?]

But this illumination of the Earth would appear to us the greatest of all if it, from station F, in which the Moon is in the very con-

junction, could be viewed; for at that time the Earth stands in opposition to the Sun, and so it is then a true Full Earth [Pleniterrium].

[Margin: The secondary light in the Moon: when is it strongest?]

For this reason, moreover, it also happens that near F the secondary light always becomes strongest and most evident — namely because of the rays reflected straight back, as can also be gathered from the lines drawn in dots.

Diagram. An engraved figure set into the text: the Sun A at the foot of the figure, with straight lines drawn from it to the circles of the Moon; the Earth B at the centre of a large circle marked as the Moon's orbit; a broad arc through B marked as the great orb; and eight lunar circles on the orbit, each half shaded, at C (top), K, D, E, F (bottom, nearest the Sun), G, H, I. Dotted lines run from B to the lunar circles. The engraver's signature stands at the lower right.

- C (top of the orbit): the Moon; below it the opposition sign ☍
- I (upper left) and K (upper right): the Moon, each marked ”Gibba” — gibbous
- H (left) and D (right): the Moon, each with the quadrature sign □ beside it
- B (centre): the Earth
- G (lower left) and E (lower right): the Moon, each marked ”Falcata” — falcate
- F (bottom of the orbit): the Moon; below it the conjunction sign ☌
- A (foot of the figure): the Sun
- ”Orbita Lunæ” (twice, along the upper and lower parts of the circle): the Moon's orbit
- ”Orbis Magnus” (twice, along the broad arc at left and right): the great orb
- ”Aut. Sc.” (lower right): the author engraved it

But as soon as the Moon advances somewhat and recedes from the conjunction, or from the line A F B C, and becomes falcate — as E and G show this appearance — then the Moon's secondary light has become smaller the more the Moon's phase has grown, and the dotted lines converge in narrower spaces; and so at the same time that light appears weaker. For at that age of the Moon and of the Earth the light has diminished somewhat and, with respect to the Moon, has become gibbous.

[Margin: The Moon's [?] secondary light: when does it appear weaker?]

For that reason it cannot cast such strong rays into the illumi-

nated part of the Moon, since these rays are also more oblique on account of the Moon's position.

At D and H, however, around the Moon's quadrature, the Earth too appears to the Moon nearly halved [bifida]; hence the secondary light is scarcely perceived by the eyes, because of the fewer and very oblique rays, as is evident from the dotted lines at D and H.

[Margin: When does the Moon's secondary light vanish?]

In the gibbous face of the Moon, at K and I, the Earth is falcate, and the two lines of vision almost converge. This is the reason why the secondary light withdraws from our sight: although some light still remains on the Earth to be reflected onto the Moon, it is nevertheless so slight that it does not reach our sight.

But when the Moon, reaching opposition, as at C ☍, has its full light, then the Earth, with respect to the Moon, is in conjunction, and with its hemisphere turned towards the Moon it is quite dark and obscure. On the contrary, the whole hemisphere of the Earth can be lit by the Moon all the more fully and strongly, as happens at every opposition at night, when the Moon rises while the Sun sets in the opposite quarter.

[Margin: The New Earth in the Moon: when?]

From this figure, therefore, as also from the others appended, it again becomes abundantly clear that, just as on the Earth we perceive with our eyes the distinct monthly illuminations of the Moon, so in the same, similar way, if we lived in the sphere of the Moon, we would also see the monthly phases of the Earth, even though the Earth turns daily about its own axis — a matter that will also be treated more fully below. Again, just as on the Earth the light of the Sun reflected by the Moon illuminates the Earth's parts, which are dense and dark in themselves, so conversely the light of the Sun reflected by the Earth can light the Moon by night.

[Margin: If we were on the Moon, we would notice the monthly phases of the Earth.]

Nevertheless, the lunar day and night are arranged very differently from our day and night. For the alternation of day and night over the greatest part of the Earth is completed in the space of 24 hours, whereas on the Moon it changes only over the interval of a month, so that one day equals nearly 14 of our days, and one night just as many days. The reason for such very long days and nights on the Moon is this: that the Moon does not turn about its own axis as the Earth does, but by its own motion, which

[Margin: The account of the days and nights on the Moon, and of their alternation.]

it completes through the twelve celestial signs in its own orbit, acquires its day and night. And so it comes about that we inhabitants of the Earth always see only one hemisphere of the Moon, and spots of one and the same kind, persisting in the one place, because the Moon never turns fully about its own axis. The Earth, by contrast, since it completes its diurnal motion in 24 hours, not only obtains from this the alternations of day and night at an interval of 24 hours, but also displays its whole globe — not merely a halved part of it — to the hemisphere of the Moon turned towards the Earth, and presents its phases and illuminations to it.

The other hemisphere of the Moon, which neither we nor the other inhabitants of the Earth can see, receives no light from our Earth, nor does it perceive the Earth by sight at all — except only that small part of the Moon's hidden

hemisphere which the Moon's motion of libration sometimes also shows to us to be seen.

[Margin: The Earth cannot reflect the Sun's rays into the hemisphere of the Moon turned away from us.]

From this it is also recognised without difficulty that, if there are living created things on the Moon, those that dwell in the hemisphere of the Moon that lies open and exposed to the Earth are, as regards light, in a better condition than those that inhabit the hemisphere of the Moon hidden and concealed from us. For although the length of the night in either half of the Moon is 14 days, the darkness in the open hemisphere is nevertheless not so great as in the Moon's hidden one, since, in place of the Sun, which is not shining, the Earth sends the Sun's reflected light to the Moon. The inhabitants of the upper hemisphere, however, are deprived of the Earth's secondary light, and so have nights wrapped in deeper gloom than the dwellers in the lower hemisphere, who face us.

[Margin: If there are living creatures on the Moon, those that inhabit the lower hemisphere of the Moon are better off than those that inhabit the upper.]

Now that on this occasion we have fallen into the contemplation of the Moon, I should like, on this walk, to cover yet one or two more stretches and to look into what else worth noticing presents itself on the Moon: namely, how it can be compared with the Earth, in which respects it agrees with it and in which it differs, and moreover what might happen to us if we were living on it.

The first question that arises here is this: whether or not the ecliptic and royal road of the Sun, observed from the Moon, with a closely similar form and declina-

tion from the equator would appear to us as it is seen here on Earth? I answer that it would not. For to the inhabitants of the Moon (to speak in this way for the sake of teaching) our ecliptic presents, as it were, an equator, under which the Moon appears to move; and the orbit of the Moon is the path and orbit of the Sun. These two circles, moreover, intersect each other at opposite places, just as the ecliptic and the equator do with us.

[Margin: Variation of the ecliptic and the equator, if each circle were viewed from the Moon.]

And yet a notable difference is also found here. 1. To the inhabitants of the Moon the ecliptic appears to depart from the equator, towards the south as much as towards the north, by only 5° 17′, which is otherwise the Moon's greatest latitude; with us this declination amounts to 23½°. Hence for them, too, the two tropics are only 10° 34′ apart, whereas with us their interval equals 47°, or thereabouts. Consequently the greatest and least altitude of the Sun, as observed on the Moon, does not vary much, nor are the variations of the days and nights perceptible. The changes of winter and summer, the shortening and lengthening of the days, and also the whole period of the ascending and descending Sun are completed with us in the course of a year; among the

inhabitants of the Moon, by contrast, they come about in a much shorter time, namely in the space of a single month.

[Margin: Distance of the Moon's tropics.]

II. Next, since it is now established that the Moon's ecliptic intersects its equator, it can easily be inferred from this that the inhabitants of the Moon, in a quite similar way, have their own solstices and equinoxes at a fixed time. Nevertheless, in these too a great difference arises between us and them. For the equinox on the Moon shifts there far more quickly than with us: in every nineteen years or thereabouts (since the motion of the nodes is retrograde) the equinox runs through all the signs. Moreover, on the Moon not only the equinoxes but also the solstices change much more, and much sooner, than here with us — not, indeed, because the equinoxes are displaced, but because the Sun appears higher to them at one time than at another, and so the ecliptic is not as immovable as it is with us. Rather, they vary constantly every month, or (to speak more correctly) every year among the Selenites, whose lunar years do not exceed about four weeks. From these things it necessarily fol-

[Margin: The Selenites have their equinoxes and solstices, as we do, though with a notable difference.]

[Margin: The lunar year is determined.]

lows that among the Selenites one year often changes not a little from another in this respect, and takes on now one difference, now another. For a clear difference is also detected in length: the longest year of the Selenites is 30 days less 4^{h} 23^{m}, and the shortest 29^{d} 6^{h} 46^{m}, etc.

3. Further, one may also ask: since the Earth's orbit intersects the lunar path — or rather the solar path (because the Selenites cannot think otherwise than that the Moon stands still) — at certain points, namely at the nodes, can eclipses also be seen on the Moon? This I for my part affirm plainly. For in the same way as with us, a twofold kind of eclipse, of the Sun and of the Earth, is visible there, just as with us eclipses of the Sun and of the Moon occur, and for the same causes: namely, when the syzygies of the Earth, Sun and Moon fall near the nodes, within the ecliptic limits.

[Margin: The Selenites have their eclipses of the Earth and of the Sun, which differ somewhat from ours.]

There is this difference, however: among the inhabitants of the Moon the eclipse of the Earth (which with us is called an eclipse of the Sun) always occurs at the time of the conjunction of the Moon and the Sun, as we put it, when the Earth is then in opposition and the Moon is intercepted between the Sun and the Earth. From this it necessarily follows that the Earth is darkened by the Moon's shadow. But since the Moon is much smaller than the Earth, the Moon's shadow is far shorter, and becomes thinner at the Earth's orbit. For this reason a total eclipse cannot occur on the Moon, much less one with a duration of totality [cum morâ]; it must always be only partial, and of brief duration. The greatest eclipse of the Earth, moreover, can hardly extend beyond 67 German miles with respect to our terrestrial globe — a space that amounts to only a

twentieth part of the Earth's disc — because both the cone of the lunar shadow and the distance between the Moon and the Earth are at their least.

[Margin: How far the greatest eclipse of the Earth on the Moon extends.]

These causes, acting together, will doubtless present the inhabitants of the Moon with a wonderful appearance of the eclipse of the Earth, especially when such an eclipse is central at the time of the visible opposition: for then a small, round, darkened patch appears in the middle of the Earth's disc, around which the larger surrounding portion of the Earth stays bright and clear. Yet this smallness of the darkening in the middle

of the Earth does not last long, but gradually contracts and at last vanishes. An eclipse of the Sun on the Moon, on the other hand, takes place at the time of opposition, as we put it, when there on the Moon it is the time of conjunction of the Earth, which is interposed between the Sun and the Moon. It is known that the Earth's shadow, even at the Moon's orbit, is much thicker and broader than the Moon's diameter, which is also why eclipses of the Moon with a duration of totality are frequent with us. For that reason, too, eclipses of the Sun on the Moon can not only be total — although with us these are very rare — but even total with a duration of totality. For in this position not only does the apparent diameter of the Sun become smaller for the Selenites; the diameter of the Earth, which is far greater than the Moon's, also spreads more widely because of its near distance to the Moon, and is larger than the visible diameter of the Moon appears to us. And for this reason eclipses of the Sun of this kind, with a duration of totality, happen more often on the Moon.

[Margin: When an eclipse of the Sun occurs on the Moon, and how great it is.]

From this one may also understand that the ancient philosophers — such as Oecetes the Pythagorean and Philolaus (as Plutarch records in *De placitis philosophorum*, book 3, chapter 11), and others — were not so absurd in calling the Moon the Antichthon [Antichtona], as if you were to say "the one opposite our Earth". In the same way Francesco Patrizi, too, writes on no discordant reasoning in book 20 of the *Pancosmia*: *"Let the Moon, then, be an Earth, and let our Earth be a Moon; nor were these two Earths, or these two Moons, made in vain by their Creator. For by their mutual likeness each cherishes the other, and they favour one another, and each receives from the other the influences by which both they themselves and the parts of each both live and are preserved."*

[Margin: Why did the ancients believe the Moon to be an Antichthon?]

4. Furthermore, since this speculation is in itself so fruitful that it spreads itself widely, I do not doubt that the kind reader, having grasped the solution of one question, will at once put another to me. For since I have asserted that our Earth can sometimes bring eclipses upon the Moon, and that the same Earth is at times full of light and at times marked by various phases, it will perhaps also please you to know what, then, I think about this question: whether or not the Selenites, in a similar way, detect spots on our Earth when it is illuminated by the Sun, as we do on the Moon.

To this, again, I answer plainly in the affirmative. For just as we observe various spots on the Moon, of which some are brighter, some darker, some more elevated,

[Margin: The Selenites can count spots on the Earth just as we can, and indeed many more and larger ones than we can on the Moon.]

others flatter, and indeed in many parts distinct from one another, so too, without doubt, the Earth presents various spots on the Moon. The mainland, together with its mountains and valleys, shows the more evident spots; lakes, forests and marshes, on the other hand, tend towards a certain blackness; but the seas and great rivers darken most of all around the full moon, while in the other phases the valleys give back a blackish colour because of their greater shadow. Moreover, I am fully convinced that the spots of the Earth are more conspicuous on the globe of the Moon, and are to be viewed with wonder, not only because of the multitude of high mountains, but also because of the several very large cities, the rivers and the seas (which here far exceed the spots of the Moon in size), and because of the many islands, large and small — since the Earth is forty-two times larger than the Moon. Therefore these spots of the Earth present themselves on the Moon in no other way than the lunar spots do, both as to their appearance and shape, and also as to the boundary of light and shadow, and the other appearances as well.

In this, however, there arises the following very great difference: the earthly spots do not persist long in one place, and are therefore not permanently visible, as the spots of the Moon remain almost unchanging for us. For the Earth, because of its diurnal motion, which it completes in 24 hours, shows the Selenites one face after another every hour, indeed every moment. Indeed, it looks to them just as if the spots were moving from west to east, since they complete their period in the space of 24 hours; for from this great and sudden changes arise. Now a certain spot is seen on the western horizon; after some hours have passed it is seen in the middle of the Earth's disc; then near the east. Near the horizon these spots appear more contracted and darker than near the middle; moreover, at each lapse of 12 hours at the full moon of the Earth, or Full Earth, other spots and another face show themselves. Furthermore, the Earth also shines on the inhabitants of the Moon more brightly at one time than at another, and it appears brighter if the hemisphere of the Earth in which Europe, Asia and Africa lie turns towards the Selenites, since in those parts of the globe there are more mountains, valleys and cities:

[Margin: What causes the great and unexpected changes of the spots on the Earth as the Selenites see them?]

Diagram. A full-page engraved plate. Beneath an engraved caption in script, the whole disc of the Moon is drawn as a circle in outline; a crescent is lit along the right-hand limb, running from the upper right round the lower right to the bottom of the disc. It is marked with crater-like rings, a large dark hatched oval on the right-hand limb a little below its middle, and hatched dark bands along its lower part; small bright points stand on the outline beyond the

lower end of the crescent. No letters stand on the disc. An engraved numeral stands at lower left, and the engraver's signature at lower right.

Caption: "Phase of the Horned Waxing Moon [?]. Observed in the 12th degree of Gemini, near limit A. At Danzig. In the year of Christ 1644, April 10, at hour 8 counted from noon, but counted from the conjunction, in hour 16 of day 4."

- Lower left: "4" — the plate's number.
- Lower right: the engraver's signature — engraved by the author.

Blank: the back of the plate sheet, with the plate showing through in mirror image.

by contrast, the Earth's light is much weaker if the other hemisphere, the one in which America lies, turns round towards them; for in the west lies the Pacific Ocean [Mare Pacificum], and in the east the Atlantic and Ethiopian Oceans, so that more water than land is then visible. Above all, the face of the Earth appears endowed with a very weak light when the Pacific Ocean is carried to the centre of the Earth's disc: for then, for the most part, nothing but waters are to be seen, especially in the western quadrant.

From this, therefore, it is clear that a far greater variety is to be noticed in the phases of the Earth than in the phases of the Moon as we see them. For not only can all the changes of the Moon be observed in the Earth's phases, but these also vary so quickly that no phase, over any longer stretch of time, corresponds in every respect to the lunar phases, with a like boundary of light and shadow and as to position. This is especially so when the phases of the horn-shaped and sickle-shaped Earth show themselves: at one moment they appear quite conspicuous in their light, because the illuminated parts include mainland; soon after they are seen in a rather dim light, because nothing but seas are turned towards the Selenites.

[Margin: More changes of phase must occur in the Earth, as the Selenites see it, than occur in the Moon as we see it.]

5. Moreover, since in the present matter there is nothing that cannot be doubted, let this question too be added to the speculative questions [ideales quaestiones]: will not this continual variation and this perpetual diurnal motion of the Earth's spots in the hemisphere exposed to the Selenites, bring them some necessary, notable and evident use? To this too I answer in the affirmative. What this use is, of what kind and how great, will be clear from what follows. For the citizens of the Moon, as is also established from the preceding, experience only a single day and night each month; or, to speak in the Selenographic manner and style, in each year, in which the Sun traverses, or seems to traverse, the 12 celestial signs for them, they have no more days and nights than one single day and one night, so that the length of that day amounts to half a month. Since this is so, one may judge from it that they do not divide their day into hours as short as we do here on earth, because for them the Sun does not appear to rise and set every 24 hours; but they doubtless adopt another

way of dividing the hours, such that among them one [hour] … a whole day, or half a

[Margin: What use can the sudden change of the spots on the Earth be to the Selenites?]

day is what such an hour equals. Each of these hours, moreover, would be cut again into smaller segments, just as, in this way, sundials [sciotherica horologia] could also be built from the apparent motion of the Sun to show their hours all the way from sunrise to sunset.

[Margin: The first benefit of the motion of the Earth's spots: it serves to make known the daily span of 24 hours.]

Accordingly, just as this is now beyond refutation, so on the other side the question is asked how the Selenites may rightly apportion their very long nights, so as not to be ignorant of how much time has already passed and how much still remains to be spent. To this I answer that they may in some measure gather the length of the night from the phases of the Earth. For when the Sun sets completely for them in the east (which for us is the west), then, directly opposite, the Full Earth begins to shine for them in the west. And once this phase has, with the passage of time, changed into a gibbous one, this is still evidence that the time is before midnight, up to the quadrature of the Earth; but when the Earth has become curved [curvata], they have a sure sign that midnight has already passed. And when it is seen horn-shaped and old, with respect to the Moon, then twilight comes on for them, the new Earth sets, and the Sun begins to shine for them again.

[Margin: How the Moon-dwellers may conveniently apportion the time of the hours.]

But here one may also observe this: just as among the Selenites the Earth is always seen waning at night, and as long as it is visible in its waning, day is not at hand and is not to be expected; so too, when day comes on, the Sun and the first new phase of the Earth are at once perceived by sight, until these two bodies gradually move further apart from each other and come to opposition. From this it rightly follows that the Moon-dwellers [Lunicolae] see the Earth waning by night and, by day, always waxing. In this way, therefore, the hours of the night can be quite well distinguished on the Moon.

But the same may be done far more conveniently from the motion of the Earth's spots. For since their revolution takes place within 24 hours, they can tell with certainty from any spot that twenty-four hours have already passed. For example, let us suppose that a certain, very conspicuous spot is found on the western horizon, as seen from our side [respectu nostri]; when it reaches the meridian of the Earth's disc, it will then be inferred beyond doubt that six hours have passed; but as soon as the same spot, to the

[Margin: From what the Selenites may gather a complete revolution of 12 hours.]

eastern horizon, has been carried, a clear sign is present that twelve hours have now flowed by. And once it has emerged again in the west, it stands as an

infallible indicator that 24 hours have gone by once more. This, then, would be a suitable way of finding the hours at night on the Moon: for, as far as I can attain by my own judgement, scarcely any better or more fitting means is available to them for learning the quantity of night-time. For if we turn our thoughts to the altitudes of the stars, or to the position of the circumpolar ones, as is done here among us, we do so in vain: among the Selenites no apparent diurnal motion is given, but only the slow proper motion of the stars, which does not serve this purpose.

[Margin: On the Moon no apparent diurnal motion is detected.]

And even if, in line with the opinion of the Peripatetics, we grant as fully as you like a diurnal motion of the tenth sphere [sphaera decima], it could still achieve nothing here: for this motion would also fall upon the Moon, and the Moon would therefore be carried round together with it. Accordingly, since none of the Peripatetics can rightly contest this, it follows that no diurnal motion of the stars can be noticed from the Moon, being a globular body carried with equal speed in the same direction; and as this too is evident of itself, there is no need to add anything more about these matters.

And this is the first, singular benefit that the motion of the Earth's spots affords the Selenites. The second is scarcely smaller than it: the Moon-dwellers, from the motion and position of the spots, can easily find out the longitude of their own place at any hour of the night and as often as they please, provided some definite spot is observed from different, separate places in the exposed hemisphere; for the inhabitants of the hidden hemisphere do not have this convenience. For us, indeed, it would be desirable to be able to enjoy, daily and at any hour, an opportunity of this kind for exploring the longitude of places, which would serve us as well as many methods together. The same would also happen with us if the Moon, like the Earth, always revolved about its own axes in the space of 24 hours. But since nothing of the kind happens in the Moon, we must bring our thoughts within the circuit of reason and make trial in various places of how far, by the motion of the Moon among the fixed stars and by the position of its spots, at one distinct time and another, in investigating the longi-

[Margin: The second benefit of the motion of the Earth's spots is the knowledge of the longitude of places.]

[Margin: The best method of investigating terrestrial longitudes would be available if the Moon were able to revolve about its own axes.]

tude of places we are able to make progress. For I have no doubt at all that, as time goes on and now that the foundations of this matter have been laid, astronomers will at last bring this business to its perfection.

Since, then, our mind has until now been wholly fixed on contemplating the nature, situation, motion, form and outline of the Moon, and, as it were, of its inhabitants, and we have walked about in the lunar sphere long enough on the feet of our mind (so to speak), come, let us return to the seats proper to us and to our native land, the Earth: our concern for brevity warns us to

do so. Let us therefore lift our eyes upward again, so that from the dwelling and ground of the Earth, though from a place well removed, we may look at the present phase of the Moon and, so advised, take note of what is still worth noting there; the rest will be left to the following chapter or to some other occasion.

[Margin: The matters of which the present phase of the Moon further reminds us.]

These, then, are the things still worth observing here: namely, that the space between the Palus Mæotis and the periphery opens more widely, and the two are separated from each other by a greater interval, than in the preceding figure; and that each of those western lakes is now visible. The reason is that the Moon is now in Gemini, and at about its greatest southern latitude. Moreover, this Palus is more widely spread and appears blacker, as we have also proved by the demonstration above. Those distinct and very black spots between the boundary of light and shadow and the Palus Mæotis, however, are nothing other than deeper little valleys, or rather the dark shadows which the Montes Alani produce. In this and similar phases the shadow visible in the valleys begins to diminish and thin out in all its parts, because, of course, for the inhabitants of this zone the Sun appears higher every day. Strictly speaking, however, it is from this time that the Sun first rises for them; and when it is the Moon's first quadrature for us, it is then noon itself for the dwellers by the Palus Mæotis. Again, when the full Moon shines on us, evening comes on for them, when the Sun is about to set; and by reason of the situation of the remaining places on the Moon, the Sun, with respect to them, also rises or sets either somewhat earlier or later — just as, indeed, with us too, because of the diffe-

rence of places. In the same way, noon too varies among them. Except that the distinction in this variation consists in this: for those who, with respect to us, appear to be more westerly, the Sun rises sooner than for those who are more easterly. With us on Earth, however, the contrary happens: for the Sun rises earlier, and reaches noon earlier, for the more easterly than for the more westerly.

Finally, here too the following question arises: whether a phase of the kind we have just had is also visible on the Moon every month? To this I reply that every month, indeed, a phase equally wide as regards the digits — indeed sometimes even wider than the present one — can recur; but it is impossible that the same boundary, in absolutely all its parts, the same breadth of the Palus Mæotis, and moreover the same space between it and the periphery, can also return, because, of course, of the motion of the Moon's libration. For this reason, therefore, the same phase of the Moon can return, as nearly as possible, only once a year, namely about the spring season — say in March, April or May — when it falls out at the same time that the Moon stands in the same sign and degree of the ecliptic and has the same latitude: for in that case this face of the Moon will agree very closely with the earlier one. And although the latitude is not always the same (because, namely, of the regression of the nodes), this

phase will nevertheless not depart much from the earlier one. The same is to be noted about all the phases of this *Selenographia* that are observed in the sign of Cancer or of Capricorn: for a phase of any such kind will at no time return except when that time of year comes round at which the phase occurs again in the same sign, since the return of such a phase is only annual. But if we also required the same latitude, then this return of the lunar phase would have to be awaited far longer still. For if we desire the restitution of exactly the same phase that we noted before, we must watch for the occasion when the Moon has recovered the same place in longitude and latitude, and the same situation, that it held at the time of the earlier observation. For when this has happened, then the returned phase of the Moon, in all its parts, to the phase previously obser-

[Margin: Why the same phase of the Moon never returns within one year.]

[Margin: On what the annual restitution of the same phase of the Moon depends.]

ved will correspond, and the two will stand in the most complete equality. The phases of the Moon that are observed about Aries and Libra, however, can occur twice in one year as like each other as possible, especially when the limits are found in Cancer and Capricorn — just as the day is equal to the night twice a year, whereas the summer and winter solstices each occur only once a year. And in the same way it stands with all the remaining phases, so that we would wait in vain, at an unsuitable time, for the return of a similar phase of the Moon unless all the circumstances just mentioned have come together — as has also been mentioned above, and in terms hardly obscure; in its proper place, however, it will be set out by us still more plainly and fully.

[Margin: When the return of the same phases is to be expected.]

CAPUT XIII.

Chapter 13.

DE LUNAE CURVATAE CRESCENTIS PHASI.

On the Phase of the Curved Waxing Moon.

Although the preceding chapter dealt with the dim secondary light of the Moon, which is seen a little before or a little after the conjunction of the Moon with the Sun, nevertheless, because not everything about it has yet been treated, and certain things still remain that deserve further explanation, I have therefore decided to point out some of them more fully in connection with the present figure — where a similar appearance can also occur — and to make good what the earlier treatment lacked.

[Margin: Why the Moon's secondary light is not everywhere like itself.]

First, then, a question of this kind can be raised here: why does the secondary light, which, as was said before, is transmitted from the Earth to the Moon by the reflected rays of the Sun, not appear equally bright in every direction on

the surface of the Moon? And from what does that bright circle arise which is always found in the circumference, joined to the dim light, and is seen next to the periphery, opposite the phase of the Moon illuminated by the Sun? In this two-part question, the reason why, in the dim light of the Moon, one part seems more conspicuous and distinct than the other (although this difference is almost imperceptible) can easily be given at the outset. For

here there is no other cause than the uneven circumference of the Moon, which is produced partly by rivers, lakes and marshes, partly by mountains, valleys and continent. For since an unequal surface arises from this variety, it cannot happen otherwise than that the secondary light of the Moon should produce some difference of appearance, since the rays can be reflected to us more strongly from one part than from the other.

[Margin: Is that bright circle in the Moon some real phenomenon?]

As for the other member of this question — namely, that bright circle in the arc of the Moon opposite the part of it lit up by the Sun — one may doubt whether the explanation of the thing is to be sought in the reflection of the Earth, or whether it is more correctly to be taken, with d'Aguilon and others, from the semi-transparent body of the Moon. For if the sphere of the Moon is held to be semi-transparent, then the light of the Sun will be able to show itself more brightly and more evidently about the periphery than about the middle, because in that part the body of the Moon is thinner than about the centre. This explanation would indeed be not only highly plausible and probable but also compelling and necessary, if a luminous circle really did appear in the dusky part of the Moon, as it does indeed seem to our eyes. But the optical tube plainly shows it to be a mere hallucination of sight, and uncovers the cause of the thing, which arises from the difference between the boundaries that bound the lunar disc suffused with that secondary light. For when we use the tube, we detect no trace of a bright circle about the periphery of the Moon; rather, that light appears entirely uniform, except, however, for the lunar spots. From this it may be gathered that this apparent aspect of the Moon about its circumference is merely a deception of our sight. For since the secondary light borders on one side on the boundary of the brighter horns of the small lunar phase, while on the other side it surrounds the Moon together with the dark air, it brings it about that the whiteness of the lunar disc on the opposite side, because of the very bright light of the illuminated phase of the Moon, thrusts itself so evidently upon the eyes and displays a luminous circle. Indeed, you will be able to recognize with your naked eye, even without a telescope, that this appearance of a bright circle on the Moon is only a fallacy of sight, in the following way: if only, beside a tower, a wall or the wall of a

chimney, you stand and look at both the dusky light and the secondary light of the Moon in such a way that, because of the solid body placed in between, the primary light and the phase of the Moon itself remain hidden: for then that bright circle seen before will appear nowhere in this dusky part of the Moon.

But as soon as you see the phase of the Moon emerging, then at once the circle in the Moon will also be visible.

[Margin: Why the secondary light of the Moon does not appear the same at every time of the year, and what the reason for this is.]

Next, one may ask here whether the secondary light of the Moon is equally great at the same time, either before or after the conjunction with the Sun, with the same constitution of the air prevailing. Here I answer in the negative: for various causes that arise can dull this light or intensify it. To understand these causes the better, this theorem must be recalled from optics: that every luminous body appears the brighter, the darker its surroundings are. From this I infer as follows: the farther the Moon moves away from the Sun after conjunction, the longer it lingers above the horizon; and the longer the Moon is seen above the horizon, the more it emerges from the evening twilight. But since, while the twilight still lasts, the air is not yet very dark, and becomes darker only as the twilight fades (at evening, that is, after conjunction), it follows that the secondary light of the Moon appears brighter outside the twilight than near it, because it then stands in a darker medium. What I put forward here, however, is to be understood correctly, of the distance of the Sun and the Moon. But if anyone wished to twist my words into this sense — as though I were teaching here that the secondary light of the Moon grows the more, the older the Moon's age — he would be attributing to me something that never entered my mind. For the contrary was demonstrated by me in the preceding chapter: namely, that this secondary light of the Moon appears the greater, the smaller the phase of the Moon is. Therefore I intend only to confirm, and to prove by clear reasoning, that the Moon can sometimes free itself from the rays of the Sun within 24 hours, and does not always need two whole days, or three, for this — as I showed at length above, in Chapter 9, where I dealt with the first phase — namely, when the Moon is at perigee and swift, and also in the

Diagram. A full-page engraved plate — "the present figure" of this chapter. Beneath an engraved caption in script, the whole disc of the Moon is drawn as a circle in outline. A crescent is lit along the right-hand limb, running from the upper right round the bottom of the disc to the lower left, narrow at the top and widening below. It is marked with crater-like rings, a large dark hatched oval on the right-hand limb with a small bright round patch beside it, and a long hatched dark area along the lower right; small bright flecks stand off the inner edge of the crescent. No letters stand on the disc. An engraved numeral stands at lower left, and the engraver's signature at lower right.

Caption: "Phase [?] of the Curved Waxing Moon. Observed [?] in the 16th degree of Pisces, near perigee and the descending node. At Danzig. In the year of Christ 1644, January 13 [?], at hour 6 counted from noon; but counted from the conjunction, in hour 21 of day 4."

- Lower left: "5" — the plate's number.
- Lower right: the engraver's signature — engraved by the author.

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signs of long descension, and is in northern latitude. At that time, therefore, the Moon is necessarily so placed that it moves higher, sets later, and struggles out through the twilight more quickly than when the contrary happens. Therefore: the more recent the Moon's phase, and the higher the Moon stands, the more brightly the Moon's secondary light must appear. And this can hardly be observed better or more plainly, in the evening after conjunction, at any other time than at the time of the vernal equinox, when the Moon is in perigee, has northern latitude, and is found in Aries, Taurus or Gemini, as I have already impressed upon you several times. Nor are the twilights very great at that season, so that hardly any more favourable time in the year is granted.

[Margin: The phase of the Moon, waxing and waning [recte: ſeneſcens]: how the light varies according to the time.]

The reasoning is not dissimilar for the phases of the waning Moon and the secondary light visible around them: in both cases an equal cause can be given why that light appears brighter at one time than at another. For it shows itself more evidently when the Moon is in the signs of long ascension (such as Cancer, Leo, Virgo, Libra, Scorpio and Sagittarius), is in perigee, runs out to the northern limit, and is not far from the autumnal equinox. In this way the phases of the Moon, waxing as well as waning, can be made almost equal. Yet this does not always happen; sometimes a notable difference occurs here. For suppose that you have seen, at the same time from the conjunction with the Sun, some horn-shaped phase of the waxing Moon, the Moon being in perigee, in northern latitude and in a suitable sign; and suppose again that you have also seen, at a like time and with the same conditions given, a phase of the waning Moon. Then I declare, with experience supporting me, that the secondary light of the waning Moon, which you saw in the morning before the coming of dawn and in the east, was, if you observed it correctly, more evident and brighter than that of the waxing Moon, which you saw in the evening after twilight in the west. Nor is this without reason: the terrestrial hemisphere that faces the eastern quarter of the Moon contains more dry land — namely Europe, Asia and Africa — and less sea and water than the hemisphere facing the Moon's western situation, opposite which lies more sea from the other hemisphere of the Earth, such as the Atlantic

and Ethiopic Ocean, which stretches as far as America. Therefore, since it is certain that sea and water do not reflect and throw back light as strongly as the continent does, it plainly follows that the Moon's secondary light is seen much more weakly around the phases of the waxing Moon than around the phases of the waning Moon. There is, besides, another cause why these degrees of secondary light occur in the Moon; it will be put forward in chapter 38, to be weighed by those whom the cause already mentioned does not yet satisfy.

[Margin: The difference between two phases of the Moon at almost equal distances from the Sun is evident; and where does it come from?]

Finally, I should like to add here another phase of the Moon, which, taking account of the time of the true conjunction, is only five hours older than the

previous one, as the recorded time amply shows. Yet an evident difference is found between the two, not only as regards the difference of the arc and of the space, by reason of the boundary of light and shadow, but also in respect of the distance from Palus Mæotis towards the east, which is greater here than in the previous figure. As a result, the greater part of Lacus Corocondametis, together with a rather prominent little hill in it, was clearly visible, although nothing of it could be seen in the preceding phase. Thus a great difference is also detected in the position of Palus Mæotis and its distance from the periphery. That a difference of this kind can occur here may be gathered by comparing the longitude and latitude that the Moon had in the one case and in the other: the former phase of the Moon was observed in the 12th degree of Gemini, near the southern limit, whereas this latter one was observed in the 16th degree of Pisces, at the node itself, or on the ecliptic, where it was without any latitude. And so, since in this face of the Moon the interval between the Palus and the periphery was found to be narrower than in the previous one, the other interval, on the left side and edge of the Moon, necessarily had to be looser and wider. This twin example serves to let anyone understand that a quite evident difference can occur between two phases of the Moon, even if they were observed at an equal time before or after conjunction; but that the one can never agree exactly with the other in every respect, unless the Moon again has the same longitude, latitude and anomaly [recte: Anomaliam; printed Anamoliam]; otherwise it is impossible.

For this reason a quite notable difference between two phases of the Moon will often be observed, even though the age of the Moon is the same, as will be confirmed elsewhere by a great many examples.

Finally, here, among many other lofty peaks of rising mountains, strikingly lit outside the boundary, the most notable is that mountain which, like a small globe at the very tip of the lower horn, stood out above the rest. It not only surpassed the others in brightness but was also endowed with a singular colour, so that it was not unlike fire, or glowing gold. The cause of this appearance I shall put off, to be discussed at another time.

CAPUT XIV.

Chapter 14.

DE LUNAE LUNATAE CRESCENTIS PHASI.

On the Phase of the Crescent-shaped Waxing Moon.

Why must the horns of the sickle-shaped and curved waxing Moon always be turned away from the Sun and point towards the east? And why, too, do the horns of the curved waning Moon stretch out towards the west? This, in accordance with experience that is beyond objection, and with our observations, is demonstrated by mathematicians both in optics and in astronomy. Nonetheless, it is also consistent with experience that these horns of the Moon do not always

keep the same position with respect to us and to the plumb-line. For the parts that end in a point incline with some tilt, this way or that: at one time the upper tip bends somewhat downward and the lower one somewhat upward; at another the upper apex rises daily more towards the plumb-line; at another both horns stand perpendicular, at right angles; and at times the ends of the boundary of light and shadow are bent downward (when, namely, the Moon is gibbous), just as after the interlunar period they were raised upward. All of this appears quite clearly from our drawings of the phases. This inclination, however, arises from no other cause than the varying position and distance of the Moon from the Sun. For

[Margin: What is the cause of the varying inclination of the horns in the Moon?]

the nearer the Moon is to the Sun, and the more recent the phase, the more the horns are raised; and the more the Moon's light has grown, and the greater the Moon's distance from the Sun, the more the upper horn tends towards the plumb-line, as anyone will easily see if he refers it to the centre of the Moon. Thus the phase of the curved Moon, for as long as it is observed within the western quadrant with respect to the ecliptic, will present itself to be seen a little higher from day to day, according as the Moon's distance from the Sun is greater or smaller.

When, however, it happens that the Moon is so far distant from the Sun, with respect to the ecliptic, that it reaches the ninetieth degree [nonagesimus gradus], then the parts of the Moon that taper to a point lie exactly on a perpendicular line. But if the Moon has also moved farther from the Sun, as happens daily after the new moon, it is nonetheless carried by the diurnal motion to the circle of the ninetieth degree, where the horns likewise stand at a right angle. When, however, waxing phases of the Moon are observed in the eastern quadrant, the Moon's horns are then seen sloping downward; the contrary happens in the phases of the waning Moon.

[Margin: What use results from a true inspection of the inclination of the horns?]

These varying inclinations of the lunar horns, if they are properly attended to, offer this first use: from inspecting them one may gather whether the Moon is in the ninetieth degree, or whether it has not yet reached this circle, or has even already passed it. Second, they always show us a line drawn through the pointed Moon and tending towards the north, from which the position of the pole of the ecliptic is inferred. Moreover, when I imagine another line to this one, cutting it by mutual crossing in the form of an X, then the approximately true position of the ecliptic in the sky also becomes known.

Furthermore, concerning observations of the lunar phases, this too deserves notice: the nearer the waxing phases are to the setting and to the horizon, or the waning phases to the rising, or the farther they are from the circle of the ninetieth degree, the steeper the horns stand; whereas the nearer the waxing phases are to the eastern horizon, and the waning ones to the western, the more

the horns appear to slope downward. For since the tips, or horns, of the Moon do not keep the same position, nor the same inclination, in all the phases listed here, that varying placement arises from this.

Diagram. A full-page engraved phase plate on a pasted leaf. Beneath an engraved caption in script, the whole disc of the Moon is drawn as a circle in outline. A crescent is lit along the right-hand limb, running from near the top of the disc at the upper right round the bottom to the lower left, narrow at its upper end and widest at the right and lower right. The inner edge of the light is ragged, with bright flecks and small rings standing off it. The crescent is marked with many crater-like rings, a large dark hatched round patch on the right-hand limb in the lower half, a long dark hatched area running down the middle of the crescent into its lower part, and lighter hatched patches. No letters stand on the disc. An engraved numeral stands at lower left, and the engraver's signature at lower right.

Caption: "Phase [?] of the Crescent-shaped Waxing Moon. Observed in the 26th degree of Gemini, near the limit A. At Danzig. In the year of Christ 1644, April 11, at hour 9 counted from noon; but counted from the conjunction, in hour 17 of day 5."

- Lower left: "6" — the plate's number.
- Lower right: the engraver's signature — engraved by the author.

Blank page (the back of the phase plate; the plate and a page of type show through in mirror image).

For, first, this variety is produced by the varying elongation of the Moon from the Sun. Second, such phases could not be observed at the same time of day — because of bad weather, that is, or business that came up, or also because of the Moon's varying rising. Moreover, on account of the varying position with respect to the nodes and the limits, some difference also arises; of this more fully in its own place, where the quadratures will be treated. Finally, the fact that the Moon's place, now one and now another, in this sign or in that at the time of observation, can plainly change the position of the horns on the Moon will be treated more fully in Chapter 42, where the horn-shaped phase of the waning Moon will be discussed.

[Margin: Why have not all the figures of the Moon's phases been represented in the ninetieth degree?]

For the rest, I could indeed have represented all the figures in the same way, as if they had been observed in the ninetieth degree, had the horn-shaped phases allowed it; but I judged it better to draw the images of the Moon just as I perceived them. Nevertheless, even from our engraved figures one can at once gather how far the Moon stood from the ninetieth degree at the time of observation. That in most of the waxing horn-shaped phases the Moon's horns seem to rise more and more from day to day, and also in the gibbous phases to tilt more and more downward, while the contrary is found in the waning phases — this arises chiefly (as anyone easily understands from what has been

said before) from the Moon's elongation from the Sun growing greater each day, and from the later rising of the Moon, or the later observation.

[Margin: What is worth recording about the phase of the Moon set out here?]

Finally, as to particulars, I have this to say here: about the present phase of the crescent-shaped Moon almost nothing singular or noteworthy occurs, except that the boundary of light and shadow (which here stands in the place of the horizon), where it cuts the Pontus Euxinus, is quite flat and even, since there is a remarkable plain there; the remaining adjacent parts, however, are rough, quite uneven and broken, because there are without doubt mountainous places and valleys in abundance in them. Note further that this phase is of the kind that was observed near the beginning of Cancer and the southern limit, at which time the greatest libration of the Moon is found on the Moon's western edge, or at a place roughly midway between west and north, namely between the Palus Mæotis [Paludem Mæotidis], the Hyperborean lakes [lacus hyperboreos] and the Moon's western periphery; or

it is a phase of the kind in which the Palus Mæotica stood, as it were, at the limit of its greatest digression. Therefore, since this very thing rarely occurs in such a phase, it deserves all the more consideration.

CAPUT XV.

Chapter 15.

DE LUNAE PLUSQUAM LUNATAE PHASI.

On the Phase of the More-than-Crescent-shaped Moon.

[Margin: There are various kinds of curved lines in geometry.]

From all the phases — those that are concave, or curved, and also those swollen out on both sides and gibbous — it is evident that the limit of the illumination, or the section of light and shadow, is a line curved in an arc; but what kind of line it is, I do not think is known to everyone. For quite various kinds of curved lines are counted in geometry, such as cochlides, conchoids, colubrines [colubrinæ], citroids, arachnoids, flexuous lines, catenary lines, spirals and others of this sort. The principal curved lines, however, in which the greatest secrets lie hidden, are these four: the circular, the elliptical, the parabolic and the hyperbolic, all of which flow from different sections of the cone, as is well known to all who are somewhat versed in geometry. And the section of light and shadow in the phases is also one of these kinds.

[Margin: The opinion of the old opticians on the shape of the illuminated phases of the Moon.]

But on which it is, and exactly what it is like, not everyone agrees. Al-Battānī holds that the lines of the phases are circular. And it is indeed true that the side opposite the Sun is an arc of the circle of vision; but the other side, turned away from the Sun, by no means — although Witelo (Book 4, Proposition 77)

seems to confirm it, saying: "The sickle-shaped figure is contained by arcs of two circles that are, as it were, equal"; on the other hand, in the same Book 4, Proposition 75, he says: "The gibbous is in general irregular." But I do not wish to inquire further into the opinion of the old opticians about the lines of the phases,

[Margin: The phases of the Moon in some way imitate an elliptical figure.]

since it is established, and has been clearly demonstrated by the mathematicians of our time, that these lines are not circular but elliptical: as, among others, Kepler, a man of admirable sagacity, in the *Astronomiae Pars Optica*, Chapter 6, page 243, this with evident

proofs has demonstrated, as has François d'Aguilon, a man most distinguished for rare learning, in Book 5 of the *Optics*, Propositions 43, 44 and 45. So it cannot happen that both sides of a phase are circular at the same time except at the most exact conjunction or opposition of the Moon with the Sun; for outside that time a straight line drawn from the eye to the centre of the Moon never becomes parallel to the circle of illumination.

[Margin: When does the light of the Moon turn out circular?]

But when it happens that the bases of the luminous part and of the part seen cut each other at right angles, and the illuminated part is smaller than a hemisphere, then it is altogether necessary that in a phase of this kind one side, the side facing the Sun, is circular, while the other is elliptical and hollowed inward — namely, the boundary of light and shadow. Conversely, if the base of the illuminated spherical part cuts the base of the portion seen at right angles, and this is larger than that, then what is seen of the shining segment is a sector of a spherical surface; but the figure appears mixed, made up of the circular outline and of the periphery of an ellipse curved outward, as happens in all the gibbous phases.

[Margin: When does a phase of the Moon reproduce an exact semicircle, when an ellipse, and when a circle?]

In either quadrature, however, the bases of the illuminated hemisphere and of the part seen cut each other at right angles. It is therefore entirely necessary not only that the whole arc and the whole surface of the illuminated hemisphere that is seen should appear as an exact semicircle, but also that the limit of the illumination should then present a perfectly straight line, as Witelo demonstrates at some length in Book 4, Proposition 76. For when the eye is placed in the same plane together with the circle, as happens in this case, the circumference of that circle will appear from a distance as a straight line, as is evident from Proposition 57 of Book 4 of d'Aguilon's *Optics*: *"If a circle is placed in the same plane in which the eye also is, the circumference of that circle will appear from a distance as a straight line."* Accordingly, outside the quadratures and the true full moons, and also the interlunar periods, the sections of the phases of the Moon, whether waxing or waning, do not always remain the same in their curvature but vary daily: either they recede further from the roundness of the circle and become obtuse, or they are drawn in further and become acute, until they

return to a circular line — according as the cones of illumination and of vision intersect one another differently from day to day, and the foci of the ellipse change. In the curved or concave phases of the Moon, from conjunction up to the first quadrature, the sections become more obtuse daily and by degrees; after

the quadrature, however, up to opposition, the sections in the gibbous and incurved phases become more acute day by day, until at the time of opposition they turn back again into a circular line; and from opposition up to the last quadrature they become more obtuse from day to day. But from this quadrature, as the sections tend toward conjunction, they are seen to be more acute every day, and so on.

[Margin: The elliptical figure of the Moon is to be understood not of its particular curvatures but of its outline.]

I should like it to be observed here, moreover, that when I speak of the elliptical lines of the phases, I exclude from the boundaries those small curvatures and flexures that are present on account of the mountains and valleys on the Moon. For I consider these lines as though the body of the Moon were an entirely smooth and even sphere; otherwise these elliptical lines would turn out not smooth but very flexuous and irregular, so that no regular figure could be assigned to these phases, especially since they change from hour to hour. Anyone who wants to know more about these matters and looks for lengthy demonstrations should consult the authors named before.

For the rest, a more exact contemplation of this figure brings up a number of noteworthy things, which have been mentioned here and there above. So whoever examines this phase carefully will grasp the whole matter all the better.

[Margin: Why are the phases of the Moon in Capricorn difficult to observe?]

Phases of this kind that occur about Capricorn, in the winter solstitial signs, are, however, harder to observe than those that occur about Cancer, in the summer solstitial signs — especially when they have a great southern latitude at the same time. For, first, those phases stay only a few hours above the horizon; then they creep along low, and even when standing on the meridian itself they do not rise higher than seven degrees. As a result, observations are often hindered and disturbed, not only by the obstruction of many tall buildings but also by the longer duration of twilight and by the dense exhalations that gather about the horizon. Nevertheless, diligent contemplators of the heavens must take pains to seize every opportunity, whenever it can be done, of observing the phases of the Moon even about Capricorn: for the greatest changes of the Moon, both as to colour and shape and also as to the motion of libration, and its

Diagram. Engraved phase plate numbered 7: the full disc of the Moon drawn in outline, with the illuminated part on the right. The boundary of the light runs from the limb near the top right of the disc down and to the left to the limb at the lower left, so that the lit part is broad in the lower half and narrows toward the top. Along the boundary lie a long dark hatched area and, in the upper lit part, a hatched area washed in violet and green; further dark

patches stand at the right limb in the lower half, and many crater-like rings are drawn, several filled black, a chain of them running down beside the boundary in the lower half. No letters stand on the disc. Engraved caption above the disc:

Phase of the Moon waxing, more than crescent-shaped. Observed in the 14th degree of Aquarius, about the intermediate points and the descending node. At Danzig. In the year of Christ 1644 December 4, at 6^h counting from noon. But counted from the conjunction, in hour 7 of day 6.

- Lower left: "7." (plate number)
- Lower right: "Autor Sculp[?]it." — the author engraved it [?]

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limits, have so far been noticed by us about Capricorn and about Cancer. Indeed, it was from fairly frequent observations of this kind, in these opposite signs, and above all at the greatest and most widely differing latitude on either side, that the limits of libration first became known to me, and that I was given the means of exploring the difference between the various horizons, and between the limits of this libration. These things I could not have investigated in the Moon had such opportunities been lacking to me.

[Margin: There is a notable difference between the phases of the Moon observed in Cancer and those observed in other places of the zodiac.]

The present phase of the Moon will declare and show this very point much better: how evident the difference is between the phases of the Moon observed about the sign of Cancer and the rest, seen in other places of the zodiac. For not only are Palus Mæotis and Mare Caspium — together with other neighbouring places, such as the Insula Major of the Mare already mentioned and the Riphæi Montes — seen much more obscure, and paler, smaller and narrower than usual; the position of these spots also varies with respect to their distance from the periphery. This becomes evident both from Palus Mæotis [Palude Mæoticâ] and above all from the twin Hyperboreus Lacus, which now touches the periphery more closely and, besides, appears in so faded a colour that it is scarcely visible even with a powerful telescope. Whenever these spots are observed in other signs, however, they not only stand farther from the periphery but also appear larger, are endowed with a darker colour, and are perceived at first sight — as is clear from the preceding figure and the one immediately following, and from many others. Where so great a difference and variation comes from has already been set out at length.

[Margin: The Lacus Hyperborei: where do they come closer to the periphery of the Moon, and where less?]

Finally, it can also happen at times in the Moon that its spots already named appear still more faded and, with respect to the limb, nearer to it. For the Lacus hyperborei can approach the periphery so closely that one can scarcely make them out — especially when the Moon is about the beginning of Capricorn and occupies its greatest northern latitude, as the following examples will show.

CAPUT XVI. DE LUNAE ADOLESCENTIS PHASI.

Chapter 16. On the Phase of the Adolescent Moon.

[Margin: Where does the inequality of the Moon in the synodic months come from?]

That the anomaly, or inequality of motion, in the Moon makes the Moon's synodic months vary is plain from Chapter 7, in which we dealt with the motion of the Moon. Since, then, the motion of the Moon is never equal and uniform, an equal interval between the conjunction of the Moon with the Sun and the quadrature is for that reason never found. For sometimes this space is completed in eight days and something over, sometimes in seven, sometimes in six and a half — so that the difference extends to nearly two days, according as the Moon is observed, in summer or in winter, about perigee or apogee. Accordingly, as many phases can occur between conjunction and quadrature as there are days running within this interval (if, that is, you count one a day), as the lunar figures amply confirm. Above all, the present figure is to be counted among those that the Moon, travelling about perigee, has brought on faster than usual. For the quadrature followed as early as the sixth day after the true synod of the luminaries, so that between the conjunction and the quadrature itself only five phases must necessarily be placed, even if none has been neglected — as phases 1, 4 and 6, this eighth itself, and the tenth prove, all of which fall in the month of April.

The following phase of the horned Moon, however, is among those that the Moon brought on by its slower motion: for at that time it took a full nine days, less a few hours, counting from conjunction up to quadrature. For the Moon stood about apogee and the Sun about perigee, so that the following phase was still two days away from the first quadrature, although, as regards the intersection of light and shadow with respect to the spots, it is found to be broader than this eighth phase now set before us.

But why the following, ninth phase of the Moon, which in the space

Diagram. Engraved phase plate no. 8: a large circle outlining the whole lunar disc, of which only the illuminated part on the right is drawn — a waxing phase short of the quadrature, with craters, dark plains and shaded uplands; the terminator runs ragged from the upper right down to the lower left, with small detached points of light standing off it in the dark part. The caption, in engraved script above the disc, reads:

Phase of the Adolescent Moon. Observed in the 10th degree of Cancer, around the greatest libration. At Danzig, in the year of Christ 1644, April 12, at the 9th hour counted from noon; but counted from the conjunction, in hour 17 of day 6.

- Foot left: plate number "8."
- Foot right: "Autor Sculpsit." (*the author engraved it*)
- No letters or names are engraved on the disc.

Blank verso of phase plate 8; the plate and the text of the preceding leaf show through.

[Margin: What did I chiefly attend to in the order of the Moon's phases?]

of one day stands farther from the quadrature than this eighth, I have placed nearer to the half Moon, although in reality it stood farther from it — the reason was this: I never resolved to follow the order of the phases according to their distance from the quadratures. My stated aim here was only to observe the order of those phases which, with respect to the spots, enlarged the section of the luminous and the shaded part — because, that is, in this respect they come closer to the phase of quadrature than the others that precede them. For had I not attended to this, the order would at once have been disturbed, and a phase appearing smaller would have followed a larger one; and this I deliberately chose to guard against, because of the unsightly appearance.

Had it been possible for me to record all these figures within a single month, they would indeed have presented themselves in a better order as regards their outward appearance. Yet that labour would still not have to be considered as necessary and useful as the present order I have kept. For only phases alike with respect to the motion of libration would have come into view, and from them neither the motion of libration nor the differing appearances of the spots that follow from it could have been derived and understood, as can now be done with less effort.

[Margin: Where do the variety and inequality of the phases come from?]

For I have observed the Moon at different seasons of the year, in different signs and degrees of the zodiac — now about the nodes, now about the limits, then about the apsides, and finally in the intermediate places — and drawn it on paper, so that from these figures the various inequalities, progressions and changes of the lunar phases cannot fail to be detected all the more conveniently. That could by no means have been done had I kept merely to depicting the phases of one lunation and another.

[Margin: Where does the notable difference between related figures arise from?]

An example that amply confirms this teaching lies ready to hand in the present phase. For had it not been observed and noted in the opposite sign, and at a different season of the year, we could neither have known nor believed that so great a variety exists between figures so closely related, as regards the luminous part of the Moon and its boundary. For from this phase it is clear that the space between the Marsh [Paludem] and the periphery is now at its widest, because the Moon is in Cancer and at the southern limit; and that two oblong spots,

are visible in that very space — namely both western lakes; just as the Marsh itself also appears rather broad and darker. The neighbouring mountains and valleys, too, are more spread out and tend towards a deeper blackness, as do the two Lacus Hyperborei, which stand still farther from the periphery of the Moon, so that Palus Amadoca is discerned quite distinctly. In the preceding figure, by contrast, the opposite happened.

[Margin: Where does the periphery of the Moon show the greatest limit of libration?]

Moreover, the western periphery of the Moon shows us the greatest limit of libration, since the southern limit had carried the Moon to a southern latitude of 4° 42′. It is also worth noting here that we are scarcely ever able to see the western edge of the Moon more exposed, and Palus Amadoca on it so clearly, as in this southern position; more often, however, we get to see much less of it.

Further, those oblong spots around Palus Mæotis are without doubt nothing other than the deep and dark hills of the Montes Alani, which shine out most in this drawing. The small half-moons that appeared in Taurica Chersonnesus, by Pontus Euxinus, and between Macra Insula and Mons Berosus, I judge to be nothing other than the meeting of a number of hills, mountains and valleys.

[Margin: Some shadowy parts in the Moon: where do they come from?]

Indeed, that blackish and shadowy area seen below Mons Dalangver, and everything similar to it in colour, I believe arises from the reflection of dense forests — if indeed there are any there — or from the reflection of a great many hills. That shadow is certainly not so easily discerned as the one that arises from the immense ridges of the mountains.

[Margin: Of what kind of substance is Pontus Euxinus?]

The boundary of light and shadow here is evidence, among other things, that Pontus Euxinus is a very wide and level plain, and in that respect not at all unlike our sea; in it, however, a great many islands, mountains and crags appear scattered here and there.

[Margin: Why do certain spots seem to be narrowed from day to day, to be filled with greater light, and to be recognised with more difficulty?]

Finally, in a like appearance of the Moon, the Montes Sogdiani, Coibacarani and Dalangueri, or their valleys, now shine out most, because the Sun does not yet illuminate those parts from a high position, and therefore bounds the valleys only around the summits of the mountains:

but afterwards they become narrower day by day, because the Sun gradually rises for the Selenites and is carried higher, and hence brings greater light to these parts.

CAPUT XVII. DE LUNAE JUVENIS PHASI.

Chapter 17. On the Phase of the Young Moon.

[Margin: The titles and inscriptions of the phases: what purposes do they serve?]

A student of selenography who has understood the libration motion of the Moon's disc well, and weighed it carefully, will gather at first sight, from the inscription of this phase, what its face can be like: how much, and towards which side, the lunar spots have librated; whether the interval between the periphery and the Marsh has been widened or narrowed; and whether the Lacus hyperborei have stood near the limb or far from it; and other things of this

kind. All of these, as we have said, are perceived from the inscription and title alone — especially if the true longitude and latitude, together with the place of the Moon with respect to the apogee or perigee, has been noted, as I have generally done at the head of the figures. Whatever may perhaps have been omitted now and then for the sake of brevity, we have hardly left untouched in the remarks.

These inscriptions are also very useful if you wish to know when a phase like this one, or like some other figure, is to be expected again that is entirely the same both as regards the librational motion and as regards the boundary. For this purpose you must also diligently turn over and search the ephemerides for the time at which a similar phase — one, that is, having all the requisites expressed in the title — will return: not only when the Moon will be similar in age, but also in its motion of longitude, of latitude and of the anomaly solved [Anomalię ſolutæ]. If all these things coincide again about a given phase (which, however, is rarely to be hoped for), you will be able to affirm without doubt that on the day expressed in the ephemerides a phase equal in every respect will appear.

But although the apogee or perigee of the Moon may be found at that time still somewhat different from the earlier one,

nevertheless the face the Moon will show will not, for that reason, be much unlike the earlier one, since the motion of the apogee contributes little here (as will be said in its proper time and place). For provided you find a phase equal in age, longitude and latitude, and at the same time visible above the horizon, there is certainly no doubt that the same face of the Moon will present itself again. Suppose, however, that no other phase at all can be found in the ephemerides than one that corresponds to the earlier only as regards longitude (such as is seen nearly every year, if the air is clear): this too, I say, will differ little, except that over Mare hyperboreum, around the Hyperborei Montes and Palus Amadoca, it will appear broader or narrower, according as the latitude, compared with that of the earlier phase to which it must correspond, is going to be greater or smaller, northern or southern. But if it is not possible to find one equal even in longitude, it will certainly be vain to expect a very similar phase — with the exception, however, of the case that can arise in signs of the kind that enjoy equal declination. For example, in Aries and Libra the motion of libration is the same (provided, that is, that neither the latitude nor the nodes are taken into account), and so too in Taurus and Virgo, Gemini and Leo, and so on. From all this it is abundantly clear how very necessary the inscriptions attached to the phases are.

[Margin: About the quadratures the daily spaces of illumination increase and decrease very rapidly.]

Further, as regards the present face of the Moon, it too is one of those crescent faces that are curved inwards, or concave, although it is the last of them all. The one immediately following is the face of the quadrature, in which the section of light and shadow has already come down to a straight line. And

it is truly remarkable that within the space of twenty-four hours (as is found from the preceding eighth phase, observed only so many hours before the tenth figure, namely the quarter) that section should have changed so suddenly. Yet this always happens. For just as about the quadratures the daily spaces of illumination increase and decrease quickly, so too the sections change and vary very rapidly at that time.

Moreover, just as this phase is almost entirely the opposite of the immediately preceding figure as regards the motion of libration, so in turn it differs little or not at all from the seventh in order, except with respect to

Diagram. Engraved plate, numbered 9, on a separate sheet set into the page: the disc of the Moon drawn as a full circle in outline, with only a thin illuminated crescent along the right-hand (western) limb shaded in. The crescent shows the dark maria, many ringed craters along the terminator, and broad bands of hatched shading near the lower limb; the rest of the disc is left blank. Engraved caption above the disc:

- Title: *Phase of the Young Moon.*
- "Observed at 22 degrees of [?], at the intermediate distance between the northern limit [Limit. B.] and the descending node [☋]."
- "Danzig. In the year of Christ 1644, November 5, at hour 6 counted from noon."
- "But counted from the conjunction, in hour 1 of day 7."
- Plate number, lower left: "9."
- Signature, lower right: "Autor Sculpsit" — the author engraved it.

No letter key and no place-names are engraved on the disc.

This page is blank: the verso of the plate leaf, with plate 9 showing through in mirror image.

age and boundary [confinium]. For the western limb of the Moon shows very nearly the true limit of least libration on the side of the Moon facing the west, so that the lacus hyperborei, lying very close to the limb, are seen as if on the periphery itself and can barely, if at all, be made out. What else, moreover, arises from a periphery librated to the utmost in this way has already been said in various places above.

The boundary, however, differs only very little from the two preceding ones in respect of distance; yet meanwhile it cuts farther into the Moon as regards the spots. For that reason it is well worth noting about this boundary that it delimits principal places of the Moon, namely Mons Serrorum and Carpathes, whose valleys are entirely in shadow, since they stand as it were on the horizon, where only the summits of the mountains are grazed by the Sun. Secondly, that boundary cuts Æmus Mons, and in part also Peronticus Sinus, Horminius Mons, Amaum, Antitaurus and Taurus, all of which are of remarkable height — as is inferred from the brightly illuminated small areas standing far off from the boundary. Above all, the greatest of all the mountains are those that surround Byzantium, not far from Pontus Euxinus — among those, that is, which on this occasion are seen at the limit of the light. For the outermost cusp [cuspis

extrema] appears to stand off from the section of the light by one twenty-sixth part of the diameter, although this phase occurred two days before the true quarter.

CAPUT XVIII.

Chapter XVIII.

DE QUADRATURIS IN GENERE, UT ET in specie de hisce tribus delineationibus Lunæ Bisectæ.

On the quadratures in general, and in particular on these three drawings of the halved Moon.

In the eighth chapter we dealt fairly fully with the Moon's motion of libration, and with its origin and properties. Above all, we said that this motion produces the greatest variation in the quadratures, both of the spots and of the boundaries: so that the sections of light and shadow pass now nearer to the west, now towards the east [Subsolanum], now straight through the centre, and a great many other things of this kind follow from it. At that time, however, because the material was so extensive, we could not yet treat all these matters as fully as the subject required — above all the progressions and retrogressions of the sections, and likewise of the quadratures, and indeed of the other phases as well, and also the particular motion of the variation of the cusps. We shall therefore take this excellent opportunity, while we are occupied with the view of these three quarters, to explain those matters more fully and clearly, adding examples as well; and we shall also carefully point out everything else worth noting on this subject.

[Margin: Why the sections of the quadratures do not pass through the centre at every time?]

From the first look at the present tenth figure, which is that of the first quadrature, it is quite plain that the line between the bright and the shadowed part deviates a long way from the centre towards the west, and bounds the illuminated part of the Moon. Why this happens may perhaps seem surprising, since every quadrature must be half of the Moon's visible hemisphere — or, what is the same, its boundary must cut that hemisphere in two. Nevertheless it is clearly seen here that the illuminated part of the Moon is much smaller than the shadowed part. Again, in the eleventh figure the boundary is far closer to the centre; but in the twelfth it has now, as it were, crossed the central line once more, and seems to have advanced further towards the east, so that the bright part appears much larger than the dark. These are surely remarkable appearances,

Diagram. Engraved plate, figure 10: the Moon at its first quadrature. A large circle outlines the whole disc; only the part to the right of an irregular, ragged terminator is drawn in light, crowded with craters, bright mountain ranges and the dark hatched spots, while the part to the left of the terminator is

left empty within the outline. The terminator runs from the upper rim, right of the centre, down to the lower rim near the centre, so that the lit part is visibly less than half the disc. Small bright points stand out in the dark beyond the terminator. No lettering is recorded in the disc.

- Caption (above the disc, in script): *First Quadrature of the Moon. Observed in the 23rd degree of Cancer, about the greatest libration. Danzig. In the year of Christ 1644, on 13 April, at 9^h counted from noon, but counted from the conjunction, in hour 17 of day 7.*
- Lower left: "10." — the figure number.
- Lower right: "Autor Sc[[u/a]]lpſit" — *The author engraved it.*

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which occur around the quadratures. It is therefore fitting — since it matters a great deal, and much follows from it — that these appearances be properly investigated, demonstrated by a dense supply of examples, and established, so that it cannot fail to be clear that all of them really exist in the Moon and that the matter is not otherwise. This, then, I shall carry out on this occasion as far as I can.

[Margin: When does the greatest and the least widening and compression of the spots occur?]

To begin with, from what has been said here and there above, I think no reader with even a little knowledge is unaware that the motion of libration now widens, and now compresses to the utmost, the Palus Mæotis [Paludem Mæotidem], as well as other places adjacent to the periphery (namely mountains and valleys), as has already been clearly shown by the examples of the preceding phases. They are extended to the utmost, as has been observed, when the greatest libration of all in the Moon is towards the south-east [Euroaustrum]; that is, so far as it has been possible to gather until now, when the Moon is at the beginning of Cancer; and again they are compressed to the utmost when the Moon is lingering in Capricorn.

[Margin: The widening and compression differ at different times.]

This widening and compression of the spots extends not only to the Palus Mæotis and the other places nearest the limb, but also to all the spots on the Moon in general. Yet this variation does not always occur in the same way, nor in a similar proportion, but always according to the spots' differing distance from the limb, or from the centre. That is, in the ascending signs the western spots come nearer to the centre and move further away from the periphery; conversely, in the eastern quadrant the spots are gradually removed more and more from the centre and, by the operation of the motion of libration, come nearer to the periphery. So at one and the same time the western spots are necessarily seen more widened, and the eastern ones, each and every one of them, much compressed. In the descending signs, however, the contrary happens: since the eastern spots are brought nearer to the centre and the western

ones nearer to the periphery, it follows that the former then appear broader and the latter more compressed, as is easily understood.

[Margin: The visible centre of the Moon's disc is movable.]

Indeed, it follows from this that the visible centre of the Moon's disc is never seen, by reason of the motion of libration, to be bound to a fixed spot and immovable; rather, it must necessarily vary continually through the whole course of the year. When, however, the Moon in the ascending signs

is located, the centre is then carried forward, in the order of the signs, from the west towards the east; afterwards, with its motion as it were reversed, it is carried backward, against the order of the signs, from the east to the west — namely, while the Moon is in the descending signs.

[Margin: And the sections of the quadratures vary.]

In this way the sections of light and shadow of the quadratures, and of the other phases, also vary; they plainly accompany this motion of the centre, which there is certainly no reason for anyone to doubt.

[Margin: It is asked why the boundaries of the quarters do not always pass through the centres of the figures.]

But here a question arises to which we must certainly respond: why, namely, do the lines of light and shadow of the quadratures not pass through the true centre of the Moon at all times, when by rights this ought to happen? For the illuminated part can be neither smaller nor larger than the darkened part — otherwise there would in truth be no quadrature at all — and yet it is evident from the tenth figure that the boundary has not yet reached the centre, but is still very far from it.

First, then, I by no means deny that, as the quadrature comes on, the illuminated part is always equal to the shadowed part, except in a very small matter, of which more will be said in its place. Secondly, it is also certain that this section is always carried through the centre in this way. That this does not always happen in these drawings of the quadratures, and was not adhered to by me, is certainly by no means to be ascribed to any carelessness or lack of diligence on our part. Rather, for many weighty reasons, and indeed for the sake of the greater usefulness that redounds to the viewer, it seemed best to set it before the eyes otherwise. For it would have been entirely possible for me to draw the boundary of the quadrature through the centre at all times, so that in our figures it would always have divided the Moon into two equal parts — if only it had been possible, in each and every phase, always to compress or to widen both the larger spots, such as the Pontus Euxinus [Pontum Euxinum], the Mare Mediterraneum and the Mare Eoum, and the others that stand out around the middle, according, namely, to the true proportion arising from the motion of libration, just as has indeed been observed at every time in the spots situated at the periphery. In truth, however, this is plainly impossible, since the contraction or extension of the larger spots that present themselves around the middle is so slight that scarcely, or not even scarcely,

can it be perceived — if not in the sections of the bright and the shadowed part at the time of the true quadrature.

Moreover, even if all these things had been possible to do, they would have been so far from helping us that they would have been a hindrance. For, first, we could never have constructed, displayed and kept any constant, general and primary figure and drawing of the phases; nor, secondly, could we in any way have shown so openly and clearly the variations of the lines and the motion of libration about the Moon's middle. On the contrary, great confusion and disorder of the figures would have arisen from it, from which I could scarcely have extricated myself; and, what is more, such things would have been of no use for anything, since the difference is so slight that it is scarcely noticed in the spots situated around the centre.

[Margin: What kind of general figure did the author construct at the outset?]

Having weighed these matters, as was proper, we constructed right at the beginning a definite and constant primary or general drawing — namely, according to the face of the Moon as it is seen in Aries and Libra, that is, at the intermediate libration, as regards the central spots. Once I had examined the true and proper proportion of the spots in this drawing on every side, I always kept that drawing unaltered and invariable as regards the larger spots and their widening. The motion of the centre, however, I arranged in this figure, as in all the others, so that at any time whatever I could describe accurately in every respect, and set before the eyes, the true periphery of the Moon according to the libration. This would otherwise have been impossible, had I always moved the spots around the centre from their place and wanted them not to be fixed at all. Furthermore, had I made the motion of the centre as wide as the greatest and least variation of the sections of the quadratures is found to be (as appears from both the tenth and the twelfth figure), and distributed that motion through the signs accordingly, I would certainly never have drawn even a single phase correctly, still less have displayed for you to behold such certainty in the motion of libration, agreeing in all respects with the observations themselves, as you see has in fact been done. For if I had also placed the centre of the Moon on the very section of this tenth figure, and described the limb from it, then assuredly the libration — the Palus Mæo-

tis and the Lacus hyperborei on the one side and the periphery on the other — would have been seen not as it is now seen, and as it actually stood in the sky at that time, but nearly twice as large as it really ought to be. The chief reason is this: since the body of the Moon is spherical, while the phases must necessarily be displayed on a plane, it is therefore not at all fitting to adopt a method of this kind. For the chief consideration must certainly be that the phases and their motions be represented in such a way that they correspond to the observations as exactly as possible. To achieve this, certainly no other means presented itself to us than the one we have always used in drawing the phases.

And so you have the chief among the reasons why the sections of the quadratures do not at all times pass through the true centre of the figures drawn, and why a certain drawn quadrature appears now smaller, now larger than the other, although they are always equal to each other, as regards both the illuminated and the darkened part.

[Margin: The sections of the quadratures have definite limits,]

But to pursue this matter further, one must know the following. Just as the motion of libration around the periphery has definite limits — as is detected from the two horizontal limbs of the greater full moons, of Cancer and of Capricorn — so too the sections of the quadratures possess their own particular and definite limits. Within this interval, namely with respect to the spots, they complete their progressions in the order of the signs, from east towards west, and then again their retrogressions, against the sequence of the signs. This space, indeed, does not at all agree in breadth with the one visible at the periphery, especially around the Palus; rather, it appears almost four times as large as the other, although in reality both are equal to each other, as was shown at length in chapter 8, page 247. For in that place I mentioned that this appearance arises because the interval at the periphery is seen by us far more obliquely than the one around the middle; hence it necessarily also appears more compressed, although, as has been said, both are equal: for near the extremities the projections of equal portions of the periphery are smaller.

These two limits of the quadratures, once indeed every year,

[Margin: When the extreme limits of the quadratures appear.]

are seen, provided that a view of that phase is granted at the time of the true quadrature: the western limit when the Moon is bisected, around the beginning of Cancer, that is, in spring; the eastern limit when the Moon is split in two, around the beginning of Capricorn, in autumn — as can be seen from the tenth and twelfth figures, which were drawn at about that very time.

[Margin: The limits are established by certain observations.]

The boundary [confinium] of the first quadrature, observed on 1644 April 13, very nearly grazes the Pontus Euxinus and crosses the mountains distinguished by the name of Catena Mundi, then the Propontis near Insula Besbicus, Mons Didymus, and so on in sequence, as is clear from the figure. This section cannot incline any nearer towards the west, as will be demonstrated below from a great many observations; so much so that it is the outermost of all those ever detected in the halved phases of the Moon. For the sake of clearer distinction I shall hereafter call it the Vernal Section [Sectio Vernalis], or Vernal Quadrature, since one of this kind has so far been seen at no other time than in spring, around the equinox.

In the twelfth figure of the halved Moon a boundary is presented that extends nearly the farthest of all towards the east, although it could still advance a little further towards the east. For this quadrature was observed not at the very beginning of Capricorn but already in the 13th degree of that sign, and moreover (which counts for most) seven hours before the true quadrature, as

will become clearer a little later from the sections of the quadratures. The true outermost section of the eastern ones, however, passes roughly through the Lacus Niger Major, namely through Insula Lesbos and Sinai Mons. In what follows I shall call it the Autumnal Section, or Autumnal Quadrature, since so far it has never come our way except in autumn. A section of this kind was observed by me in 1644 on September 9, at 9^h counted from noon — but counted from the conjunction, in hour 16 of day 9 — in the first hour before the true quadrature, with the Moon at 23° Sagittarius, that is, about the beginning of Capricorn, in the 5th degree of northern latitude, and at the northern limit.

Between these two extreme limits, moreover, all the quadra-

[Margin: Within a definite interval the sections of the quadratures perpetually carry out their reciprocations.]

tures and their sections that ever appear in the sky are seen. In the first half-year, from spring to autumn, the sections are moved forward, in the order of the signs, from west to east, according as the quarters [Quadræ] are found each month in successive signs of the zodiac, one after another. Afterwards, from autumn, these sections run back again against the order of the signs, from east to west, and each month they are moved a sixth part further, or carried backwards (if it happens that those sections are observed at the time of the true quadrature), all the way back to springtime, when the quadrature arises again in Cancer.

But if at the very moment of the quadrature no opportunity of seeing them is given (as usually happens when the quadrature falls in the daytime, so that it is seen only in the sixth, seventh, or even the eighth hour before or after the true aspect), then the sections cannot keep to their limits accurately and strictly either, so that they appear now more remote, now nearer: for the spaces of illumination of the sections vary extremely quickly around the quarter.

[Margin: The monthly sections of the quadratures are represented in a diagram.]

To make these things easier to grasp, I shall append a figure — namely a part of the primary drawing — which expresses the position, shape and proportion of the spots in simple lines as carefully as possible. By means of it will be shown not only the Vernal and Autumnal Sections of the quadratures, with the Moon staying in Cancer and in Capricorn, with respect to the spots, but also those intermediate spaces; and also how the sections vary at different times of the year, in the different signs of the ecliptic. But you must remember that all these sections necessarily occur around the limits; otherwise they incline a little towards one region or the other, as will shortly be said about this at greater length. The outermost line of all, A, the western one, shows the appearance of the boundary at the time of the true first quadrature, with the Moon in Cancer; such a face, as will be clear from the lunations and very many other observations made in earlier years, has so far always been observed by us around the vernal equinox. The other, B, shows roughly the place of the section — namely, where it could reach if the Moon's true qua-

rter is located around Leo or Gemini. The third, C, shows it if the quarter should happen to fall around the beginning of Virgo or of Taurus. The fourth and middle line, D, presents the appearance of the section of the summer and winter quadrature, occurring in Libra or Aries.

Diagram. A rectangular woodcut set into the left half of the text block: a simple outline drawing of a part of the Moon's face, with spots rendered as small rings and irregular closed outlines, crossed from top to bottom by seven parallel vertical lines marking the successive boundaries of the quadratures. The lines are lettered along the top and again along the foot. A cluster of very small engraved symbols in two rows stands about halfway down the block between the lines; it was not read [?]. A small italic mark stands at the foot right of the block.

- Top of the lines, left to right: G, F, E, D, C, B, A
- Foot of the lines, left to right: G, F, E, D, C, B, A
- Foot right: "Aut. S[?]"
- Centre, between the lines: small symbols [?]

The fifth line shows roughly the place of the boundary when the quarter is observed in Scorpio or Pisces. I observed a similar example myself in 1644 August 10, at 7^{h} counted from noon, but counted from the conjunction, in hour 1 of day 9, and immediately in the first hour after the true quadrature, with the Moon staying in 19° of Scorpio, at 5° of northern latitude, near the northern limit. The sixth line shows it when the quadrature occurs in Sagittarius and Aquarius. Finally, the last is the Autumnal Section, with the quarter in Capricorn. I saw a section of this kind with my own eyes — to say nothing of the others — in 1644 September 9, counted from noon, as I reported a little earlier. And so in the first half-year, from spring to autumn, as I was just saying, the sections advance forward in the order of the signs; in the second they are carried backward with entirely the same motion.

The arrangement of the quadratures of the waning Moon is exactly the same as regards these reciprocations, except that a section — for example A, with the Moon in Cancer — is seen not in spring but in autumn; so that, in the contrary manner, from autumn until spring, they are always moved forward in the descending signs, from west to east, in the order of the signs:

As a result, each month the quadratures appear more compressed and narrower. Afterwards, from spring until autumn, they again proceed against the order of the signs (namely, while they are in the ascending signs), and each month appear wider and larger with respect to the spots.

[Margin: The sections of the quadratures are confirmed by observations.]

I shall prove by observations that this is so: first, the Vernal and the Autumnal Section, by the tenth, the thirtieth, the twelfth and the thirty-second; and I shall present a great many more of these observations when the lunations are discussed. You will notice that the remaining intermediate points also correspond very well to the eleventh and the thirty-first phase, no less than to those drawn from the lunations just mentioned.

[Margin: The reasons why those sections are either advanced or held back.]

But do not be disturbed, kind reader, if at first sight some sections seem to you, in your judgement, somewhat unsteady. For the chief reason for this (as I reported a little earlier) is that the quadratures do not always arise at the beginnings of the signs, and only very rarely can the true moment of these phases be observed. For it usually happens that they were observed and drawn some hours before or after — and this matters a great deal to the question. Four hours introduce a difference about as great as the interval lying between two points, and eight or nine hours one twice as great. For even if, for example, the waxing quarter occurred in Leo but were first observed only after the eighth hour, then its section of light and shadow would certainly appear to you not at B, the point of Leo, but at D, the point of Aries, since that much light can very well accrue to the phase in so many hours. I demonstrate this as follows. In the space of 24 hours the sections of the quadratures make an interval as great as the two extreme lines A and G — that is, those of Cancer and of Capricorn — comprise between them, as the lunations confirm. If, therefore, this space is divided into six equal parts, as has been done here, you will certainly find that four hours belong to each space. From this we can now gather without any trouble how far these sections of the quadratures can differ from the points shown, if ever those phases — not at the time of the true quadrature,

but some hours later or earlier — have been observed: that is, how far backward or forward they appear.

If, then, these things, as well as all the others that can advance or retard the sections, are properly observed in the examination of the quadratures, I have no doubt at all that the sections of the half Moon agree as well as possible with the earlier division of the libration, even though at first sight they may perhaps seem to waver.

[Margin: The half-yearly or annual motion of the sections of the quadratures is not always uniform.]

So much, then, said briefly about the progressions and retrogressions of the sections that arise from the simple motion of the libration in longitude. But a few points still remain to be noted: namely, that the half-yearly motion of the sections — of the quadratures as well as of all the other phases — is not continuously uniform through those six signs, nor alike to itself at all times, although in the preceding diagram it was divided into six entirely equal parts. For that motion closely follows the motion of the Sun and the Moon; and the sections likewise reach this point or that according to the situation of the luminaries at apogee or perigee, where they are slower or faster.

[Margin: Why the monthly spaces of the sections have not been marked according to the inequalities that belong to them.]

The reason why the spaces have not been marked off according to such a proportion is, first, that this would have been impossible to do; second, that in matters of this kind, which are extremely small, it is in my judgement quite superfluous, since many other obstacles occur daily that can produce a

greater difference than those arising from the motion of the anomaly [anomaliæ ſolutæ]. For instance: first, if the true time — or rather the visible time — of the quadratures is not always attended to; second, when the Moon is illuminated by the Sun over more than half of itself, and that still unequally, according as the luminaries were at apogee or at perigee — of which more fully in due course; third, because the motion of the Moon's latitude also varies these points noticeably, and indeed in exactly the same way as was found for the motion of the centre. Since this is so, I consider it by no means necessary to inquire more precisely into this whole business; rather, it seems enough that the monthly variations of the quadratures be divided into only six equal parts.

And indeed we have now set out these reasons in some part: namely, why the monthly lines of the quadratures

[Margin: The monthly lines of the quadratures, as of the other phases, do not continually move in parallel lines.]

vary now more, now less. But we must also by all means bear in mind how, when, and to what extent the motion of the Moon's latitude can vary these reciprocations. In the preceding figure, indeed, the monthly lines run perpendicularly through all the signs; yet you have no reason to persuade yourself that the progression and retrogression continues in this way for ever. Rather, you should know that these lines very frequently change and vary not a little, in the upper part of the periphery as much as in the lower, although about the middle they appear nearly equal in distance. That is, they are not always carried in parallel lines; but very often, at a fixed time, they lie now with the upper cusp toward the west and the lower toward the east, now with the upper cusp toward the east and the lower toward the west. Hence it comes about that the section of light and shadow presents itself now one way, now another, with respect to the spots: at one time the boundary [confinium] almost grazes a particular spot in the upper or the lower part of the Moon, at another it again stands quite far from it — even though the progression about the centre of the section, which arises from the motion in longitude, is entirely one and the same.

[Margin: For what reason does the variation of the cusps arise?]

This motion, which in the manner just described so remarkably varies and distorts the cusps of the halved phases and also of all the other phases (let this be well noted), does not arise, as I was saying a little earlier, from the Moon's motion in longitude, but in fact from its motion in latitude and from the Moon's varying position with respect to the nodes and limits.

[Margin: To determine the variation of the cusps properly is a matter of skill.]

Easy as these things may be to say, yet to investigate, explore and properly determine the variation of the sections of the quadratures — as also the greatest and least variation in degrees, which derives from the motion in latitude — is certainly a matter of skill and labour, especially since that small quantity is very

slight and hardly noticeable in observation. And indeed (if I may state the truth without boasting) I am the first to undertake to explain this matter.

For the rest, all this can be accomplished by no other route more successfully than by attending to the quadratures themselves, since from the sections of the other phases the matter does not turn out equally accurately. To investigate this matter, however, four, five or six observations are not enough; a great many more are needed, through

all the signs, degrees and cases, taken in longitude as well as in latitude. Such observations, however, are obtained only with great difficulty, because to grasp correctly in the mind and to record observations of this kind in such very minute matters is not only difficult but also very treacherous: in the upper part of the Moon's periphery, as in the lower, notable points rarely present themselves; and besides, observations of this kind demand not a modest span of time but continuous and careful attention over many years, if anything certain is to be determined in this way at all.

[Margin: How great is the variation of the cusps?]

As far as I can judge for the present from my observations, of which I have a very great many at hand, these lines vary by up to about five degrees counted on the Moon's periphery, both in the upper part and in the lower. Now, above, they are moved forward toward the front, more and more in the order of the signs; now they are carried backward against the series of the signs. This happens in the waxing as well as in the waning phases, according as the Moon has been placed in the limits or in the nodes, southern or northern. So, by reason of the Moon's various positions and latitudes, besides those earlier motions of libration in longitude and in latitude (mentioned in the eighth chapter), a third motion arises, which for clearer distinction we shall call in what follows the *Motion of Libration of the Cusps*, or the *horizontal Libration or variation of the Cusps*.

So that anyone may grasp this motion more easily, we shall illustrate what we have just said with various examples and observations of the quadratures, made at different times and in various positions with respect to the nodes and limits. First, as I did a little earlier, I shall enter these sections of the quadratures in a particular figure, so that, once that is done, you may at once perceive how this variation of the cusps proceeds. And it can also easily be shown in this way that the variation just mentioned is not greater than five degrees in the upper or the lower part of the periphery — that is, that it does not incline more than five degrees toward one side or the other.

In the attached diagram — a part, that is, of the principal delineation — various lines are seen, some of which

are parallel to one another, while the rest are inclined. All of them, however, are sections of the quadratures, observed by us with the greatest care at different times and in different positions of the Moon with respect to the limits and nodes: that is, they show the situation and arrangement the sections had relative to the spots.

Diagram. An engraved figure set into the left of the text: a rectangular strip of the lunar surface drawn in outline (craters, ridges and the edges of the spots), crossed from top to bottom by a sheaf of nearly vertical straight lines, some parallel and some slightly inclined to one another — the boundaries of the quadratures described in the text. Letters stand at the heads and feet of the lines, several with a small node sign beneath them, and legends are engraved vertically along some of the lines. The plate is signed at lower right.

- Heads of the lines, left to right: E (with G close beside it), L, F, D and H, K and C (with B just below), I and A.
- Node signs beneath E/G, L, D, C and A: five small signs of the ascending or descending node [?] — their form is not settled on the scan.
- Legends along the lines, left to right: "Circa Limitem Boreum." (About the northern limit); "Circa Limit[?] Bor." (About the northern limit); "Circa Limitem Auſtr." (About the southern limit); "Circa Limit. Auſtr." (About the southern limit); "Circa Limitem Auſtrinum" (About the southern limit).
- Feet of the lines, left to right: G, a small unread mark [?] above L, L, H, C, B (raised), A, I.
- Lower right: "Aut. Sc." (the author engraved it).

The four parallel lines A, B, C, D are sections of the halved phases placed about and near the northern node; F and G, about the northern limit; E and L, about the southern node; and I, K and H, about the southern limit.

[Margin: In what place is the greatest inclination of the sections found?]

From these sections anyone will now gather without difficulty — especially one who considers them diligently and accurately — how, in what place and at what time these boundaries of the quadratures change. The greatest variation or inclination, however, is found at each node, so that the sections already mentioned, when the quarter stands about the southern node and again about the northern node, are never parallel, but always make a definite angle of inclination of 5° when compared with one another. By contrast, all the lines of the bright and dark part of the bisected phases that occur about the southern limit as well as about the northern not only stand perpendicular with respect to the preceding ones [reſpectu antecedentium], but are also continually parallel:

just as all the observations made about the limits and noted in the preceding figure, taken together and one by one, clearly prove. The rest, however, observed about the nodes, show a different inclination, as can be seen above all from line D, observed about the northern node, and line E, observed about the southern node. That this angle does not exceed four degrees, however, comes about because section E was drawn not exactly in the southern node itself, that is, the point of intersection, but nearly two degrees beyond it. That the inclination of the remaining sections, namely D, C, B and A, is exactly as I reported a little above is confirmed above all by the fact that on this point they all agree as one; and more of them will be brought forward in their own time and place. And the matter will also become more evident from the boundaries of

all the other phases, if — as can be done without difficulty — they are examined more carefully. It is indeed truer than true that I did not lay down these sections at my own pleasure, nor from a persuasion formed in advance; rather, I marked them just as the observations dictated them to me. And to me myself it seems a truly wonderful thing that in so subtle a business everything agrees so accurately and so exactly.

[Margin: Various observations of the sections of the quadratures.]

So that these observations of the sections of the quadratures, already mentioned, may deserve all the more credence, may be compared more easily with the boundaries of the halved phases recorded in the Lunations, and so that others may draw similar ones from the sky itself, I shall on this occasion also determine both the very moment of time of these observations and in what degree of longitude and latitude these quadratures were observed.

1. B. Waning quadrature, observed in 10° of Virgo, near the northern node and the apogee. In the year 1643 December 3, at 5^h after midnight; but counted from the opposition, in hour 12 of day 8, 3 hours before the true quadrature.[12]
2. D. Waning quadrature, observed in 12° of Libra, having a latitude of 2° north, not far from the northern node. In the year 1644 January 2, at 6^h after midnight; but counted from the opposition, in hour 23 of day 8, at the time of the true quadrature.
3. K. Waxing quadrature, observed in 1° of Cancer,

and at the same time in the southern limit itself, namely in 5° 12′ of latitude. In the year 1644 March 15, at 7^h counted from noon; but counted from the conjunction, with the seventh day complete; at the seventh hour after the true quadrature.

4. I. Waxing quadrature, observed in 23° of Cancer, about the southern limit, in 4° of latitude. In the year 1644 April 13, at 9^h counted from noon; counted from the conjunction, in hour 17 of day 7.
5. C. Waxing quadrature, observed in 26° of Leo, about the northern node, having only 1° 30′ of southern latitude. In the year 1644 May 13, at 8^h counted from noon; counted from the conjunction, in hour 8 of day 8, 5½ hours after the true quadrature.
6. G. Waxing quadrature, observed in 23° of Sagittarius, about the northern limit. In the year 1644 September 9, at 9^h counted from noon; counted from the conjunction, in hour 16 of day 9, 1 hour before the true quadrature.
7. F. Waxing quadrature, observed in 13° of Capricorn, about the northern limit. In the year 1644 October 8, at 7^h counted from noon; counted from the conjunction, in hour 21 of day 8, 7 hours before the true quadrature.

[12] here and in the entries that follow, the unit of the figures counted from the opposition or conjunction and to the true quadrature is not printed; hours are understood.

Very like this one, another waxing quadrature was observed in 19° of Scorpio, about the northern limit. In the year 1644 August 10, at 7^h counted from noon; but counted from the conjunction, in hour 1 of day 9, 1 hour immediately after the true quadrature.

8. E. Waxing quadrature, observed in 28° of Capricorn, having a northern latitude of 2° 20′, not far from the southern node. In the year 1645 April 19, at 4^h in the morning, 3 hours before the true quadrature.
9. A. Waxing quadrature, observed in 12° of Leo, only one degree distant southward from the northern node. In the year 1645 May 2, at 8^h counted from noon; counted from the conjunction, in hour 18 of day 7, 2 hours before the true quadrature.
10. H. Waning quadrature, observed in 22° of Gemini, in a southern latitude of 4½, that is, about the same limit. In the year 1645 September 13, at 2^h after midnight, 4½ hours after the true quadrature.
11. L. Waxing quadrature, observed in the 5th degree of Aquarius and the 1st of northern latitude, not far from the southern node. In the year 1645 October 27, at 9^h in the evening, at the time of the true quadrature.

Diagram. A full-page engraved plate of the waxing half moon. The whole disc is outlined; the lit half lies on the right, its terminator running down a little left of the centre, with the spots, craters and mountain ranges drawn in detail and small lit peaks standing out beyond the terminator in the dark half. The dark half is left as bare outline. No letters or names are engraved on the disc. The caption, engraved in italic above the disc, reads:

The Bisected Moon, Waxing. Observed in the 7th degree of Gemini about the limit A. Danzig. In the year of Christ 1644, on the 15th day of March, at the 7th hour counted from noon; but from the conjunction, with the 7th day complete, that is, at the 7th hour after the true quadrature.[13]

- Lower left: plate number "11."
- Lower right: signature, "The author engraved it."

The quadratures just cited have been drawn with straight lines in the preceding diagram. I could also have shown more of them, but I deliberately left that out to avoid confusion: for let us put off the rest, which are still at hand, until the time when the drawings of the lunations are brought forward.

[Margin: The motion of the inclination of the cusps explained more fully.]

To make this motion of the libration and of the inclination of the Moon's cusps clearer, we shall try to make this subject, which is very intricate and obscure, still more perspicuous by means of the present figure and observation. Let us suppose, then, that some section of a waxing quadrature has been observed which touched the Moon's periphery above at about the 25th degree, and below at the 205th degree, the Moon being, of course, near the southern limit, as happens in this phase. I say, therefore, that even if at another time a similar

[13] "limit. A." is printed; whether "A." abbreviates *Austrinum* (southern) or is a letter is not settled on the plate. "□ram" is the engraver's sign for *quadraturam*.

section returned in longitude by reason of the monthly variation, but the Moon was near the northern node, the section would then vary by about five degrees, in such a way that above it will cut the 22nd degree of the periphery, but below about the 200th degree. But if at that time the Moon was near the southern node, then even though the section passed through the same spots near the lower limb of the Moon (for example, about the 200th degree just mentioned), this section would nonetheless again vary not a little in the upper limb with respect to the preceding section. For in such a position of the Moon it would incline 2½ degrees more towards the eastern side, just as near the northern node it happens farther towards the west; so that at that time it would reach about the 28th degree in the upper limb, although in the lower part, as I was saying, it still held the same 200th degree. The difference therefore extends to 5 degrees and a little beyond. Quite a similar variation is also detected at the proper time in the lower periphery (if, that is, a fixed point of the line of illumination is kept above), so that the cusps' motion of variation can likewise vary there by 5 degrees. With this difference, however: if the Moon were in the northern node, the section in the lower part would tend not towards the west (as in the former case, where that fixed point was set below) but towards the east; again,

when the Moon is near the southern node, this section already mentioned would incline not towards the east but towards the west. This is clearly evident from the preceding diagram.

But what is the chief reason for this, and how does it come about that the boundary [confinium] of light and shadow always presents one appearance with respect to the spots near the limits, another near the northern node, and finally a quite different one near the southern node? And further: why, likewise, in the Moon's quadratures, when the Moon is, that is, in about the ninetieth degree, do the same degrees of the Moon's periphery not always culminate, but the sections of the lit and the shaded part in the upper limb incline farther towards the east [Eurum] when the Moon is in the northern node, and towards the west near the southern node, than they do near the limits? I shall now explain it graphically.

First, then, it has become sufficiently known from what has gone before that the Moon's orbit is never parallel to the ecliptic, but continually intersects it at certain opposite points, namely the nodes. Hence the ecliptic and the Moon's orbit also always form an angle, which equals five degrees, more or less (for this angle varies, as is plain from the Moon's motion), so that one half of the Moon's orbit above the ecliptic tends towards the north, and the other towards the south, as appears in the accompanying figure. In it the line parallel to the horizon represents the ecliptic; A, the place of the Sun; the curved line D B C, the Moon's orbit. These lines intersect each other by a certain law at the points D and C: at C lies the northern node, at D the southern node, and at B its limit.

So when the Moon is near the limit (for example, at B), we have noticed that the line — or, to speak more correctly, the section of light and shadow —

which descends straight from the culminating point e through the centre to f presents a definite appearance with respect to the Moon's spots, in such a way that it intersects the Moon's orbit perpendicularly, that is, at right angles. This perpendicular at the same time shows, when the Moon is at the limits, the true and genuine section of the lit and the shaded part, that is, of the quadratures, in such a way that the line e f, the Moon's orbit at an-

gles that are normal, intersecting it, and the section of illumination at that time either coincide in one and the same line or are always seen to be at least parallel; for near the limits the Moon's orbit, on account of its very slight curvature there, is almost parallel to the ecliptic.

But when the Moon is near the northern node, as here at C, where the Moon's orbit intersects the ecliptic at a certain angle, there the line e f, perpendicular to the Moon's orbit, does not coincide in one line with the boundary of light h g, but necessarily forms a certain angle as well. Hence in the upper limb e f inclines towards the east, whereas h g, the section of illumination reckoned at the same place just mentioned, inclines towards the west with respect to the spots, as the lines of illumination A h and A g, issuing from the Sun A, clearly show. So it comes about that near the northern node all the sections of the quadratures (and also each and every section of the other phases, to which this applies equally), compared with the sections that appear near the limits, are carried and advanced in the upper limb farther towards the west and towards Pontus Euxinus or Lacus hyperborei, and in the lower limb, in turn, more and more towards the east. All the observations without exception bear this out, and it can also be plainly gathered from the preceding figure, in which the various sections of the quadratures were presented.

Diagram. An engraved figure set across the full measure in the middle of the page. A straight horizontal line, labelled "Ecliptica" (the ecliptic) on each side, runs across the figure; at its centre is the point A, with "Sol" (the Sun) engraved above it. A curved line, labelled "Orbita" (orbit) on each side, dips from the left to the right of the figure beneath the ecliptic. Three shaded globes of the Moon, with their spots, stand on it: one at the upper left under the letter D and the descending-node sign ☋; one at the lowest point of the curve under A, with B beneath it; and one at the upper right under the letter C and the ascending-node sign ☊. Each globe is crossed by a vertical line and by other diameters, and straight lines run from A to the outer globes. Small crescent signs ☽ stand on the orbit line on either side of the middle globe. In the lower part of the plate is engraved the one phrase "Circa Limitem … Austrinum." (near the southern limit), split by the middle globe: "Circa Limitem" to its left, "Austrinum." to its right. The engraver's mark "Aut. Sc." stands at the lower right.

- D (upper left): point on the orbit, with ☋ (the southern node) beneath it
- C (upper right): point on the orbit, with ☊ (the northern node) beneath it
- A (centre, on the ecliptic): the Sun, with "Sol" above

- B (bottom centre): the lowest point of the orbit, under the middle globe
- e, f, g (left globe): e at the top of its vertical line; f and g at its foot
- e, f (middle globe): e at the top; f at the foot
- e, g, f (right globe): e at the top; g and f at the foot
- "Ecliptica" (twice), "Orbita" (twice), "Circa Limitem", "Austrinum.", "Aut. Sc."

It is otherwise, however, with the perpendicular line mentioned so often, when the Moon, that is, stays near the southern node, with respect both to us and to the Sun; for that line, as appears near D,

inclines towards the west in the upper periphery, whereas before, at the northern node, it tended towards the east. The section of the true quadrature, h g, at the same place above, tends more towards the east, away from Pontus Euxinus, whereas the contrary was found in the earlier position; and the lines A h and A g near the southern node attest the same.

From this it is clearer than daylight that the Moon, in such different stations arising from its latitude, must necessarily incline and vary its face, and the sections both of the quadratures and of all the other phases, continually in one way and then in another, so much so that a certain motion of libration of the cusps must arise from this. From this, moreover, the spots too are seen, with respect to the ninetieth degree, now in this way and now in another by reason of the inclination, as if the Moon had been librated towards one side or the other at a fixed time — as indeed actually happens in the Moon, as experience attests. Above all, this difference, or libration, proceeding from the latitude, is very conspicuous in full moons near the ninetieth degree; you will learn more about these a little later, when the full moons themselves are discussed.

[Margin: The libration of the cusps also has its own inequalities.]

Moreover, this libration of the cusps too is not always the same and constant in every month, but is subject besides to another, smaller inequality, and that inequality varies in the way that the angle between the ecliptic and the Moon's orbit varies. For that reason this libration too now increases, now decreases, together with this angle; except that this inequality and difference, I admit, is very small indeed (for it extends only to a few minutes), so that it can hardly, if at all, be detected in these observations.

And with this let us at last conclude what has been said in general about the monthly and annual progressions and retrogressions of the sections, both of the quadratures and of all the other phases, which proceed from the motion in longitude, and also what has been said about the variations of the cusps of the quadratures and of the other phases, which arise from the motion in latitude.

[Margin: The three preceding quadratures are especially noteworthy.]

Except that it may seem of no small use besides to make this known to all, right at the very end of this chapter, so that the three quadratures, likewise drawn, namely phases 10, 11 and 12, may be well noted, especially for the following reasons. 1. Because of the different

Diagram. A full-page engraved plate of the waxing half moon. The whole disc is outlined; the lit part lies on the right, its terminator running down a little left of the centre, with the spots, craters and mountain ranges drawn in detail and small lit points standing beyond the terminator in the dark part. The dark part is left as bare outline. No letters or names are engraved on the disc. The caption, engraved in a cursive hand above the disc, reads:

Phase of the Half Moon, Waxing. Observed in the 13th degree of [?]. Danzig. In the year of Christ 1644, October 8, at 7^h counted from noon; but counted from the conjunction, in hour 21 of day 8, 7 hours before the true quadrature.[14]

- Lower left: the plate number "12."
- Lower right: signature, "The author engraved it."

The back of the plate leaf is blank; the plate and the preceding text show through.

progression and retrogression of the line of illumination, and the variation of the cusps. For the first and second quadratures, namely the tenth and eleventh phases, were observed in Cancer, and indeed near the southern limit; the third, namely the twelfth phase, in Capricorn, near the northern limit. 2. Because of the different limits of the libration, visible at the upper and the lower limb of the Moon. For since 10 and 11 stand in Cancer, and moreover in the greatest southern latitude, the space between the Palus Mæotis and the Hyperboreus Lacus Superior on the one side and the periphery on the other is seen at its widest; and so, for this reason too, the lake and the marsh just mentioned are, as is apparent, spread out to the greatest extent. In the twelfth figure, by contrast, you see how greatly these spaces are compressed and narrowed, and no less the same marsh and lake; for at that time the Moon was in Capricorn and at the northern limit. A quadrature of that kind is certainly seen only very rarely.

[Margin: The motion of libration and its limits are confirmed by observations not only of mine but of others too.]

From these, once again, that motion and its limits of greatest and least libration, which stand at the beginning of Cancer and of Capricorn, are established. For the rest, we can demonstrate this openly and beyond doubt not only from all my other, countless observations, but also from many others made by Pierre Gassendi, a man most distinguished for the excellence of his learning and a friend we hold in the highest regard, and by Ismaël Boulliau, a man of outstanding intellect and the keenest judgement (the latter mentions them in his *Astronomia Philolaica*, book 2, chapter 13). But since carrying this out here would take far too long, and we have already been more long-winded than we expected, there is no need to say more here; these observations will be reserved for their proper place and time, when the different periods of the lunations are discussed.

[14] "□" is the engraver's sign for the quadrature.

CAPUT XIX.

Chapter XIX.

DE LUNAE PLUSQUAM BIFIDAE PHASI.

On the Phase of the Moon More than Halved.

[Margin: Quadratures sometimes equal this phase in size.]

The present figure, the thirteenth in order, is the first of all that begins to be gibbous. A quadrature too can, admittedly, occur at a certain time that is equally large, and whose limit between the bright and the dark part passes through roughly the same spots; except that at that time the boundary, around this halved phase, is entirely straight and not curved in the least. This may be gathered from the motion of the disc's libration in longitude and from the various quadratures that were observed in Capricorn; but above all from the twelfth and the thirty-second phase, and from the figure of the preceding chapter, in which the limits of the sections of the quadratures are marked. But since this phase was drawn in Cancer, that is, in the opposite sign, the section was therefore able to extend so far into the Moon as early as the first day after the quadrature.

Further, various things worth noting are to be observed in this phase. 1. The peaks and small areas in the upper part, very conspicuous outside the boundary, are the summits of the mountains that encircle the Lacus Niger Major. The two brighter cusps on the very limit of the light, and the third outside it in the dark part, are the Insulæ Balearides. The little half-moon emerging below them is part of the mountains that crown the island Corsica.

[Margin: Which mountains are loftier than others?]

Next, this figure also shows most clearly which mountains are higher than others, even though they are already flooded with the Sun's light on every side. For this is inferred from the shadow that those mountains cast from themselves into the valley lying below, as was already mentioned above, in chapter 8. For the blacker the shadow appears in the valleys — at an equal distance, that is, from the line of illumination — the loftier those mountains are than the rest. For higher opaque bodies cast a greater and blacker shadow than lower ones, according to

Diagram. Phase plate 13: the Moon more than halved, the lit part on the right and the boundary of light running down the left of centre, ragged with mountain peaks and with small bright cusps standing out in the dark part beyond it. The engraved caption above the disc reads:

Phase of the Moon More than Halved. Observed in the 14th degree of Cancer, around the points of mean distance. Danzig. In the year of Christ 1644, March 16, at 9^h counted from noon; but counted from the conjunction, in hour 2 of day 9.

- Lower left: "13." (the plate number)
- Lower right: "Autor Sculpſit." (*The author engraved it*)

The disc itself carries no engraved letters or names.

The back of the plate leaf is blank; the plate and the preceding text show through.

that optical theorem: *A multiplied shadow is darker* (François d'Aguilon, book 5, proposition 63, p. 426). For just as light grows by the addition of another light, so too shadow becomes darker when another shadow is added to it.

From this it is gathered most plainly that the mountains — among others Phœnix, Cragus, Cadmus and Antilibanus — far surpass Sipylus, Masicytus and Libanus in height. For the present figure shows that the shadow of those valleys is darker than the shadow of these, although these lie nearer than those to the line between the bright and the shadowy part.

[Margin: The circumference of the valleys seems, in appearance, to grow and to shrink.]

Moreover, this too deserves to be noted and considered here: how much smaller the Montes Dalangueri, Coibacarani and Uxii — or rather the circumferences of their valleys — appear in this phase than in the preceding tenth, eleventh and twelfth; and that from day to day they shrink more and more in their figure, by as much as the Moon itself gains light each day, until around full moon they vanish almost entirely, as all the waxing phases of the Moon confirm. The reason for this phenomenon has already been indicated more than sufficiently in chapter 8, to which I refer the reader.

[Margin: This phase deserves to be examined with a telescope.]

Finally, I urge lovers of the stars to take pains in procuring the best telescope and, once they have it, to survey this phase of the Moon and observe it attentively: above all for the great variety they will find here beyond the other phases, and for the incredible delight they will draw from it. For in this state and appearance of the Moon the greatest part of the loftier mountains and valleys that occupy the Moon's visible hemisphere will be displayed in a most conspicuous, most pleasing and better form — which you will look for in vain in a more advanced phase.

CAPUT XX.

Chapter XX.

DE LUNAE GIBBEROSAE CRESCENTIS PHASI.

On the Phase of the Waxing Gibbous Moon.

If ever at any time the boundary [confinium] between the bright and the dark part has been even, and not in the least rough and winding, it is certainly seen to be entirely of that kind in this phase. For the section [sectio] cuts across the Mare Mediterraneum around Insula Majorica, Sicilia, Zacynthus and Creta, and at that time the longest line is seen that can ever cross any lunar sea. And so, since in that place it runs almost entirely across waters — or, if you prefer, across a certain very spacious plain — it necessarily appears both perfectly straight and perfectly flat. The smaller areas flashing out beyond the section are the summits

of certain mountains and islands. Now the great circle, brightly lit, at roughly the middle of the line of illumination, is Mons Ætna of Sicilia, whose valley at this time is as dark as it could ever become: for the Sun (properly speaking) is only now rising on it, so that it can touch with its light only the summits of these mountains.

[Margin: Why Insula Sicilia appears darker than usual in this phase.]

Insula Sicilia itself likewise appears quite dark in this phase, and at present no very great difference in colour is detected between this island already mentioned and the Mare Mediterraneum. It is therefore rightly asked where this comes from; for this island ought by rights to present itself not a little brighter, since it is part of the Moon's mainland. The answer is that this is indeed so: for the land of the Moon, being a more opaque body, is better able to resist the Sun's rays, and can therefore also reflect them more strongly (as was said earlier) and appear brighter. That it turns out otherwise here, however, must be ascribed to the countless, most varied and wonderfully inclined mountains that are seen in abundance here and there, partly in the neighbourhood of this island and partly on the island itself; and beyond doubt still more of them exist there. But since they are lower, for that reason by no means

Diagram. Phase plate 14: the waxing gibbous Moon, the lit part on the right and the boundary of light running down the left of the disc, its upper part nearly straight across the dark seas and its lower part ragged with crater-rings and mountain peaks; a few small bright points stand out in the dark part beyond it. The engraved caption above the disc reads:

Phase of the Waxing Gibbous Moon. Observed in the 19th degree of Aries, not far from perigee and the descending node. Danzig. In the year of Christ 1643, December 19, at 10^{h} counted from noon; but counted from the conjunction, in hour 15 of day 9.

- Lower left: "14." (the plate number)
- Lower right: "Aut. Sculpf." (*The author engraved it*)

The disc itself carries no engraved letters or names.

Blank: the back of the plate leaf, showing only the plate and the preceding text through the paper.

is a view of them granted. These mountains, however, because in this configuration of the Moon they lie very close to the boundary [confinium], for that reason cast from themselves at this time a very great, very long and very dark shadow; so that from these countless mountains, variously inclined and situated, an almost continuous shadow is produced everywhere in Sicilia. So much so that it could hardly be otherwise than that this island presents a dark and blackish face for us to look at.

[Margin: Insula Sicilia appears now darker, now brighter. The reason for this phenomenon is investigated.]

You may reply, however: if what you have just related rests on some solid foundation, then this island must become brighter and more luminous day by day as the Moon waxes, because the shadow too diminishes and grows thinner as the Sun rises higher there. And here again I affirm that this is indeed how

the matter stands; and that it cannot happen otherwise I shall demonstrate by reliable observations of the Moon both waxing and waning. For just as Insula Sicilia becomes brighter and more luminous day by day while the Moon grows, so conversely, while the Moon wanes, it becomes daily, little by little, darker and blacker — as you will find in fact if you carefully weigh the following phases 15, 16, 17, 18 and 19. At full moon, indeed, and a little after, it will at all times be very bright; but as soon as the Moon wanes noticeably, as happens in the twenty-sixth phase, it at once begins gradually to be overshadowed, so that day by day, in the phases following in order, it becomes more shadowed, up to the 34th and 35th phase. At that time it appears very dark once more, since it is then again placed almost on the boundary itself.

[Margin: Sometimes the line cutting across a sea is somewhat rough and uneven.]

That the line of the section [linea sectionis] below Sicilia is not seen to be altogether even or smooth, even though it still passes across water or plain, arises from this: the line runs straight through Insula Creta and Sepher Mons, with the result that it must necessarily be winding.

Finally, this too should be noted: Palus Amadoca, not far from Hyperboreus Lacus Superior, stands out almost on the very periphery of the Moon. The reason is that the Moon was observed at that time around the middle of Aries and the southern node; for otherwise, with the Moon in Cancer, this lake, well removed from the limb, is

seen; but in Capricorn, especially around the northern limit, little or almost nothing of it is seen. Moreover, in this phase only the smaller western lake presents itself to us, while the other, larger one lies hidden in the periphery this time; but in Cancer both always present themselves clearly and distinctly.

CAPUT XXI.

Chapter XXI.

DE LUNAE IN ORBEM INSINUATAE PHASI.

On the Phase of the Moon Rounding into a Full Circle.

[Margin: And the sections of the trines move back and forth in turn.]

That a trine of the Moon cannot occur at any other time than when the Moon is removed from the Sun by four whole signs — that is, is 120° distant — does not in the least escape even those who have so much as greeted astronomy from the threshold. This phase shows such a trine. But there is no reason for you to suppose that the sections of the bright and the shadowed part run in like manner, continuously, always through the same spots, just as this aspect of the Moon always occurs at a certain fixed distance, and as can likewise be seen in this phase, in which the boundary [confinium] proceeds through Insula Ficaria, the Ærii Montes, Insula Malta and Insulæ Didymæ. Rather, it is not seldom advanced with respect to the spots, now nearer towards the west, now

farther towards the east, in the manner of the sections at the quadratures; and this reciprocation likewise takes its origin from the Moon's motion of libration.

[Margin: On the extreme limits of the trines.]

Those two extreme limits of the sections at the trine, between which each and every line of illumination moves back and forth at the time of the trine throughout the whole year, are shown to us by the preceding fourteenth and the following sixteenth phase. For when the Moon is in Capricorn, that is, when Palus Mæotica is very close to the limb, the section at the trine is similar to the section of phase 14, in which that boundary [confinium] enters near Insula Sardinia, Mons Ætna and Insula Creta. But if the Moon is observed at the time of the true trine in Cancer, when Palus Mæotis by contrast is as far as possible from the periphery, then the section appears nearly equal to the one which, in

Diagram. Phase plate 15: the Moon rounding into a full circle, drawn within a full outline circle. The lit part fills most of the disc; its boundary of light runs down the left side, ragged with crater-rings, and the dark crescent beyond it is left blank inside the outline. The disc shows the dark seas, many ringed craters (some tinted in colour in this copy), and bright rays radiating from a crater near the lower right. The engraved caption above the disc reads:

Phase of the Moon rounding into a full circle. Observed in the 3rd degree of Cancer, both around the greatest libration [?] the limit A [?]. Danzig. In the year of Christ 1644, February 17, at 7^h counted from noon; but counted from the conjunction, in hour 10 of day 10.

- Lower left: "15." (the plate number)
- Lower right: "Autor Sculpfit." (*The author engraved it*)

The disc itself carries no engraved letters or names.

The back of the plate leaf is blank; only the plate and the facing text show through.

the following sixteenth phase, is found, and which runs across Sinus Apollinis, Insula Cercinna, Mare Ægyptiacum, Sinus Sirbonis, etc.

[Margin: The limits of the trines are entangled with certain inequalities.]

Now if you make an observation a little before or after the true trine aspect, then the sections cannot keep so strictly to these limits either; rather, they are pushed more and more towards one side or the other, in proportion to the time. An example of this is now before our eyes as well. For this phase was observed seven or eight hours later than it ought to have been with respect to the trine; for that reason its section is also seen to have already passed beyond the true limit. Indeed, since the Moon was at that time entirely in Cancer, its boundary [confinium] too ought rightly to have passed through Mons Ætna and Insula Creta. The reason it turned out otherwise is, as I was saying just now, that the Moon was observed eight hours later, that is. Meanwhile, however, you may rest assured about these limits of the trines, since from my innumerable observations it has become known to me as more certain than certain that the matter is not otherwise — as the following lunations will likewise show

abundantly enough. Meanwhile, however, a certain similar (though slight) variation, or inequality, also shows itself about these limits, just as about the quadratures; but since it is found to be of entirely the same nature as the former, I consider it superfluous to pursue this inequality at greater length.

Once these limits of the trines have been examined and grasped, then, and the space lying between them divided into six equal parts according to the order of the ascending and descending signs — as was done above for the quadratures, namely in the figure inserted at p. 329 — we can also henceforth, with no trouble, predict and determine without doubt and with certainty each and every section of the trines visible throughout the whole course of the year, or that will ever occur at any other time; and we can draw most accurately, with respect to the spots, the section corresponding to a given time. Above all, however, this business will succeed much more accurately still if in this respect you also attend carefully to the motion of the libration of the cusps.

Finally, this too should be noted: in this phase Mons Ætna, Insula Creta and Mons Sinai, when they stand so close to the line of illumination, are much more pleasing and agreeable to look at than they can ever otherwise be; above all, Ætna gleams like a most precious pearl. For this reason this phase fully deserves to be carefully considered and examined by investigators of celestial things.

CAPUT XXII.

Chapter XXII.

DE LUNAE INCURVATAE CRESCENTIS PHASI.

On the Phase of the Inward-Curved Waxing Moon.

[Margin: On the secondary spots of the lunar seas.]

When we examine and weigh properly and accurately the colour of the waters and seas of the Moon — such as Mare Mediterraneum, Mare Caspium, Pontus Euxinus and Propontis (their colour is always darker than that of the islands and continents) — we notice that the colour of the lunar waters is varied and by no means uniform. This is borne out not only in the present figure but in all the remaining figures as well; and I have attended to this diversity of colours at all times, in all my observations, to the best of my ability and with the greatest accuracy. These secondary spots of the waters, however (as I am pleased to call them), are never varied or changed, but always, as far as appearance goes, keep the same figure or form. This phenomenon certainly seems unusual and remarkable, so much so that it will hardly be beside the point to look into it more deeply and to investigate its genuine cause, as far as may be possible.

[Margin: Where do these spots come from?]

Indeed, the opinion is deeply settled in my mind that, just as our terrestrial seas are not altogether bare and empty, but have been enriched here and there by God, the Best and Greatest, with many, indeed innumerable, islands and

rocks, so the lunar seas too, by reason of the same matter, may be filled with no less various islands, mountains and rocks; and no small part of all these things can be perceived every day, distinctly and clearly, with an excellent telescope. Meanwhile, however, perhaps still much

Diagram. Engraved plate 16: the Moon in the inward-curved waxing phase, drawn as a large disc within its outline circle, the illuminated part shaded with the seas, mountains and spots in fine hatching; the caption is engraved in a cursive hand above the disc. No lettering is recorded in the disc.

- Caption, line 1: Phase of the inward-curved waxing Moon.
- Caption, line 2: Observed in the 7th degree of Aries, near perigee and the descending node.
- Caption, line 3: At Danzig.
- Caption, line 4: In the year of Christ 1643 November 21, at 7^{h} counted from noon.
- Caption, line 5: But counted from the conjunction, in hour 3½ of day 11.
- Lower left: 16.
- Lower right: Autor Sculpsit [engraved by the author].

more numerous islands, and those innumerable, may exist there in those seas, but smaller and scarcely perceptible. Because of the immense distance, the weakness of the eye and the imperfection of the telescope, they for the most part elude and escape our sight, so that we can scarcely, indeed hardly at all, make out such things perfectly. And lest this should perhaps seem to anyone not only very surprising but downright absurd, let him consider, I ask: if we were on the Moon, would we be granted such a view of the Maldive Islands of the East Indies, or of the islands of Greece, that we could not only discern them perfectly but also count them? I certainly do not doubt that everyone will agree with me that this is plainly impossible, and that so distinct a vision could never arise in our human eye. That being so, I truly do not see why something similar could not occur in the lunar seas, something that we grasp by sight with equal difficulty. Perhaps, indeed, there too, scattered here and there, lies a huge crowd of islands, whether Maldives or many other very small ones, which for the reasons just given cannot be distinguished by us at all. It therefore cannot be otherwise than that such places in the seas appear to us somewhat paler and a little brighter, because there the water seems to be mixed with land, that is, with islands. But in those parts of the water or sea where no islands, marshes, rocks or anything else is noticed, but only water, those places are necessarily seen as both darker and more uniform than the rest, just as the secondary spots, namely, present themselves in this phase as in all the others. If, moreover, there are in certain places reed-beds, thickets and other kinds of aquatic shrubs of this sort — which is indeed credible, and even highly possible, since such things are found in abundance in our seas too — it will certainly not be incongruous that from such things, both varied and very widely different, a differing reflection of the Sun's rays should be produced, so that this place or

that, being either more shadowy or brighter by reason of its distinct opacity, cannot fail to be perceived by sight.

As for the mountains, or rather valleys, of Ætna and Sinai, further: in the accompanying sixteenth phase these are now not so

full of shadows as in the preceding 15th phase, and above all the 14th. For the boundary [confinium] of the shadowed part is moved farther and farther away from them, the higher the Sun rises at that place. For this reason the shadow, both in these valleys and in the others, is shortened and compressed day by day until it vanishes altogether — namely, when the Sun stands almost vertically over them. This is seen at the time of full moon, when the deepest valleys, previously very dark with shadows, appear flooded with light on every side and very bright, as all the following phases plainly attest.

[Margin: On the somewhat elongated spots of the Apenninus.]

Finally, from the somewhat elongated, very black spots visible on Mons Apenninus, one may infer that very deep valleys, caverns and pits exist there. The preceding phases show this most plainly, above all the thirteenth, where those caverns are seen far blacker still. In the following figures they decrease day by day in respect of shadow, up to full moon, and are gradually flooded with more light, in the manner of the other valleys. In this respect, however, the Apenninus differs not a little from the other mountains and valleys: it does not decrease in the same way as it grows. For example, as the Moon waxes it gains more light day by day; for that reason, then, as the Moon wanes it ought to grow darker and darker from day to day, like the rest of the mountains and valleys. Yet it is evident that things appear otherwise on this Apenninus. After opposition it is lit by the Sun just as brightly as the other mountains; indeed, at the time of the last quadrature it is seen almost brighter still. The chief reason for this phenomenon is this: the highest peaks of all the mountains lie on the western side, and while the Moon waxes these cast a considerable shadow toward the east, onto the surrounding mountains and valleys. The remaining summits, the eastern ones, are lower and rise gradually upward, and so they produce only a very weak shadow; on the contrary, they appear far more luminous after the Moon's opposition than before it.

CAPUT XXIII. DE LUNAE GIBBEROSAE CRESCENTIS PHASI.

Chapter 23. On the phase of the gibbous waxing Moon.

[Margin: The Moon, like our Earth, consists of thoroughly heterogeneous parts.]

The matter of the terrestrial globe, of which mountains and valleys on the one hand and plains on the other are composed, does not consist entirely of homogeneous parts of one and the same nature and quality. The same holds for the opaque matter of the Moon, or Antichthon, which we can surely compare to nothing more fittingly than to our own Earth. For the lunar mountains,

valleys and plains differ very greatly from one another in their matter: one place is rocky, another sandy, and of these again some are of one kind and some of another, consisting partly of a bluish-grey sand, partly of a reddish one, and so on. So that these things may not seem the dreams of a sleeper or the fictions of a waking man, but plainly in accord with reason, I have resolved in this chapter, with the present figure in view (as can very fittingly and conveniently be done), to demonstrate them in such a way that you cannot fail to agree with me. And yet, I confess, I seem very bold even to myself in taking on a work of such magnitude, since I am about to discourse on things both so remote and unheard of in earlier times, and in doing so to blow away, as it were, altogether the celestial fifth essence of the Peripatetics. But truly, since I know well that in so arduous an undertaking I am well supported by observations that do not waver and by the experience of my own eyes, I have no doubt at all that this plan of mine will succeed.

First: that rocky places and crags of various kinds occur here and there among the lunar mountains I have already partly reported in chapter 8. There I said that it is not contrary to reason that all valleys of the kind that vary not at all in form or shape, but that from the first day of their illumination — that is, while the Moon is waxing — by no means decrease or contract day by day, are crags and rocky mountains. For sandy mountains, not as steeply

can they rise upward; rather they are more sloping, and toward the summit they rise more and more into a pointed apex. For this reason their valleys too, below and around the feet of the mountains, are narrower than around the peaks; so that of necessity they must decrease day by day in the waxing phases of the Moon, just as they must grow in the waning phases.

[Margin: Another reason.]

Next, there remains yet another reason, which likewise moves me to believe that crags and stony places of this kind can exist on the surface of the Moon. Those valleys and mountains which, although they are not higher than the rest, nevertheless far surpass the rest in brightness and splendour at the time of full moon — as, among others, Mons Ætna, the mountains of Insula Creta, Mons Sinai, the mountains of Insula Besbicus, and so on — these, I say, are of a stony nature and better suited, because of their greater opacity and solidity, to reflect the Sun's rays better and more strongly; and from this a light altogether greater and more powerful is produced. Suppose, however, that the lunar mountains consisted of one matter only, namely sand or mud: then it would certainly be impossible for their reflection of the Sun's rays to be so varied and diverse. Instead, all the lunar mountains, together with those valleys, would always be seen equally luminous, and none would excel the others in brightness. But since the reflection is observed to be so varied and diverse, it certainly follows that the valleys and mountains are composed of the most diverse matter, like our terrestrial globe. I say, therefore, once again that those places which are more luminous and more splendid than the rest are rocky. For more solid bodies

reflect light and the Sun's rays more strongly than less hard ones, and therefore also appear brighter than these, as is amply demonstrated in catoptrics.

[Margin: First objection.]

But suppose you object to me that other reasons too can be given why one valley appears more splendid than another: that this happens, namely, because one is deeper than the other, so that the higher they are, the greater the variety of reflection that arises from the surrounding mountains, variously inclined; and that for this reason such valleys necessarily present a brighter appearance too, like the ones already mentioned, Ætna, Creta, Sinai and so on? Just as I do not deny these things, since they are plainly so, so too I grant them all; but rightly

Diagram. Engraved plate 17: the Moon in the gibbous waxing phase, drawn as a large disc within its outline circle, the illuminated part shaded with the seas, mountains and spots in fine hatching and the dark limb at the lower right; the caption is engraved in a cursive hand above the disc. No lettering is recorded in the disc.

- Caption, line 1: Phase of the gibbous waxing Moon.
- Caption, line 2: Observed in the 13th degree of Leo.
- Caption, line 3: At Danzig.
- Caption, line 4: In the year of Christ 1644 February 19, at 10^{h} counted from noon.
- Caption, line 5: But counted from the conjunction, in hour 13 of day 12.
- Lower left: 17.
- Lower right: Autor Sculpsit [engraved by the author].

Blank verso of the plate leaf; the plate shows through in mirror image.

understood, nevertheless. Meanwhile, I ask you to tell me why not all valleys alike in depth are also seen equally bright at the time of full moon — for example Insula major Caspii, Mons Serrorum, Mons Carpathes and others. That these, however, are of altogether the same height as the former, we can easily demonstrate from their first and last appearance, namely when the boundary [confinium] of light and shadow lies closest to them. Here, then, nothing remains for us to answer but this: that those valleys may be darker in part, and partly marshy as well, and wooded, and covered with shrubs. If that is granted, it necessarily follows that they cannot fail to show themselves darker to us. Add to these that the more luminous places and the whitish mountains are perhaps of gypsum, which would likewise pass their light to us more clearly and strongly, while the rest consist of a blacker matter. I do not deny that what you have adduced is by no means contrary to reason; and I myself hold that diverse mountains of this kind can be found on the Moon. If that is so, the same follows as before: that varied and most diverse mountains and valleys, with respect to their matter, exist on the Moon.

[Margin: Mons Porphyrites shows for certain that mountains most diverse in respect of their matter exist on the surface of the Moon.]

Moreover, on the surface of the Moon yet another mountain is found that first rises in this phase: namely Porphyrites, in Mare Eoum, above Insula Cercinna. It plainly confirms that some mountains are, in respect of their matter, altogether most unlike other mountains. And I have no doubt at all that this Porphyrites consists either of reddish earth, like the Porphyrites of Egypt (after which we named the lunar one), or — what seems to me more consistent — of a nitrous or sulphurous matter. Indeed, I am convinced that it feeds a perpetual fire, and so is one of the fire-spewing mountains, such as we have here: Mount Etna, Hekla, Vesuvius and others.

[Margin: The reasons by which the author was chiefly moved to hold an opinion of this kind.]

And to hold this I am driven by a reason that is certainly neither small nor light. For since, at every time without exception, in all the Moon's changes, I have plainly and clearly observed that Mons Porphyrites always presents itself, as to colour and splendour, quite otherwise than all the others that stand anywhere in the visible hemisphere of the Moon, and displays a saffron, or yellowish, colour, or a golden or fiery one; which colour is, as it were, natural and perpetual to it; (since from the first

day of illumination, at once and right up to the last, it does not vary in this respect), just as all who are equipped with a good telescope may find by experience at any time. For this reason, then, I have been compelled, willing or not, to conclude that this Porphyrites either consists of red rock, or of sand or reddish earth, or else is outright burning, or overflowing with perpetual fire. For if these things must be likened to earthly things — and for the sake of rightly informing our mind it cannot be done otherwise — no other definite things present themselves with which they can be compared more fittingly.

[Margin: Neither to an error of sight, nor to an illusion of the tube, is this phenomenon to be ascribed.]

Accordingly, since this appearance can in no way be ascribed to an error of sight, nor to a deception of the telescope (for just as this matter came before my gaze, so it will be detected by all who do not refuse to make the experiment of it, with no exception of time; they will notice that there is a great difference between Porphyrites and the remaining lunar mountains, whether they use one tube or several, and these prepared from any segment whatever), it follows altogether that certain lunar mountains are composed of varied and diverse rock, sand or mud — not to say that some are fire-spewing, as we have just understood of Porphyrites. And it seems to me highly credible that several others like it lie hidden there (among which must also be counted that mountain we mentioned toward the end of Chapter 13) and exist, of a nature and quality of this kind; but because they are smaller and lower, we are by no means allowed to view them so accurately and distinctly.

[Margin: What shape Porphyrites has.]

Moreover, this too is most noteworthy: that this Porphyrites never fails to present an appearance, in respect of form and figure, quite different from that

of all the other lunar mountains. For about its middle it consists, as it were, of a round body, from which a kind of curved horn runs out toward the south; above, toward the north, a curved peak is likewise seen, but one entirely torn away from the middle body — so much so that, with that gap lying between, like a part of the sea, it can be clearly made out. There is also found another mountain, namely the one named Pyramis, near Mons Argentarius, beside Lunae Promontorium of Mare Mediterraneum; it likewise displays a strange form or figure, and is not unlike a pyramid, from which it also took its name.

Diagram. Engraved plate 18: the Moon in the phase of the Mature Moon, drawn as a large disc within its outline circle; the illuminated part fills almost the whole disc, leaving a narrow strip along the left limb inside the outline circle, where the boundary of the light is drawn rough and notched. Seas, mountains and spots are shown in fine hatching, with rayed spots at the left and lower centre. The caption is engraved in a cursive hand above the disc. No lettering is recorded in the disc.

- Caption, line 1: Phase of the Mature Moon.
- Caption, line 2: Observed in the 8th degree of Cancer.
- Caption, line 3: At Danzig.
- Caption, line 4: In the year of Christ 1644 January 21, at 11^{h} counted from noon.
- Caption, line 5: But counted from the conjunction, in hour 13 of day 13.
- Lower left: 18.
- Lower right: Autor Sculpsit [engraved by the author].

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Yet to these three mountains just named, none on the nearer side of the Moon is found to be equal in appearance, however carefully you look into it, even through every single phase.

CAPUT XXIV.

Chapter XXIV.

DE LUNAE ADULTAE PHASI.

On the Phase of the Mature Moon.

[Margin: On Insula Cercinna and its colour.]

In the phase set out here, the whole island of Cercinna now appears not a little brighter than in the preceding seventeenth; and the reason is easily drawn from what was said in Chapter 20 about the similar appearance of Insula Sicilia. For since on Insula Cercinna, likewise, countless tracts of mountains and rows of crags are found in abundance, as is detected from those luminous rays, it likewise happens that, when the boundary [confinium] of the shadowy part lies in the neighbourhood of that island, the island is seen blacker, because those countless mountains cast very long and very dense shadows from themselves at that time. The middle of this island, however, since it is marshy (though

conspicuous for a mountain standing up in it), therefore also appears somewhat more shadowy.

[Margin: On Mare Syrticum and the lunar Nilus.]

Mare Syrticum, however, which lies below Insula Cercinna just named, is suffused with a greater paleness than the rest of the sea, and is moreover filled here and there with brighter small areas; from this it is gathered without difficulty that it is, as it were, shallow, or, to speak properly, that it abounds in crags here and there. Into this sea run certain winding lines, just as if they were very large, sinuous rivers discharging themselves into the sea at this place. Further, since the Nile, with a series of various branches coming between, likewise enters our Syrtic Sea, which is equally shallow, I have therefore decided to call those lunar rivers too by the name of Nilus. The places that it flows past and washes, however, appear to be marshy and not at all dry, as is presumed with certainty from their colour; and for this reason too that Nilus agrees still better with our terrestrial one. For you know that ours not infrequently floods those neighbouring places; and hence perhaps for the Selenites too a similar … of the places lying around the Nile, by reason of their colour,

will be the appearance; but with this difference, that the flooding of our Nile will sometimes seem to the Selenites to vanish, whereas the marshes lying around the lunar Nilus always present the same appearance to us.

As regards the motion of libration, of both this phase and the following one: it is found at its greatest westward variation, namely where the gap between Palus Mæotis and the periphery is seen widened most of all; for these two phases were observed not only in Cancer, as is evident from the inscription, but also near the southern limit.

CAPUT XXV.

Chapter XXV.

DE LUNAE AD OPPOSITIONEM VERGENTIS PHASI.

On the Phase of the Moon Verging towards Opposition.

Once the Moon, then, has come very close to opposition, the greatest metamorphosis shows itself around the mountains and valleys. For the valleys that were previously the blackest of all — that is, at the time of their first appearance — are now seen brighter and more luminous than at any other time (since the Sun then stands almost vertically above them, so that it can flood them with direct light): namely Vallis Ætna, Insula Creta, Vallis Sinai, Insula Besbicus, Vallis Sipyli, Didymi Masicyti, etc. Yet not all valleys are equally bright around opposition. The reason is the one I gave above in Chapter 23: namely that, at the bottom, not all of them are equally levelled and equally rough. Add to this that in those darker valleys there perhaps exist very vast marshes, reed-beds, thickets, groves, etc.; and since these absorb the greatest part of the Sun's rays, so that by no means all of them can be reflected to us

from its less opaque surface, it comes about that a certain darkness arises from this.

[Margin: On the colour and the strange form of Insula Rhodus.]

The darkish spots, however, that appear at this time besides the seas are lakes, marshes and pools, as is seen still more clearly from the Selenographic Map. Among the remaining

Diagram. Engraved plate 19: the Moon in the phase verging towards opposition, drawn as a large disc within its outline circle; the illuminated part fills almost the whole disc, with a narrow darker band along the right-hand limb, broadest toward the lower right. Seas, mountains and spots are shown in fine hatching and stippling, with rayed spots at the left, at the lower centre, and a long bright streak running from the lower-centre rayed spot toward the left. The caption is engraved in a cursive hand above the disc. No lettering is recorded in the disc.

- Caption, line 1: Phase of the Moon Verging towards Opposition.
- Caption, line 2: Observed in 21° of Cancer.
- Caption, line 3: At Danzig.
- Caption, line 4: In the year of Christ 1644 January 22, at 11^{h} counted from noon.
- Caption, line 5: But counted from the conjunction, in hour 14 of day 14.
- Lower left: 19.
- Lower right: Autor Sculpsit [engraved by the author].

Blank page: the back of plate 19, with the plate and type showing through from the other side of the leaf.

spots, islands, valleys and mountains there is found a certain island named Rhodus, which is for the most part flat and even, and is surrounded by no mountains. It presents a wonderful appearance, at which I have often marvelled not a little: namely, that this island just mentioned appears entirely dark and black on its upper, or northern, side. If this happened on its right or its left side, and the island were ringed about with mountains, there would be nothing to wonder at. As it is, however, no mountains at all are seen there, as the earlier observations most clearly attest; moreover, this happens even at true opposition, that is, the island is quite darkened on its upper side. I confess, then, that it is very difficult to establish anything certain on this matter, and to search out the genuine and sufficient cause of this phenomenon.

This much, at any rate, is placed beyond all hazard of doubt: that this island Rhodus lies in an exceedingly vast marsh, which has almost the shape of a rhombus, as can be seen from all the phases. The dark part of the island, however, I cannot count among the marshes; otherwise it could not be so black, but would show a colour like that of the surrounding marsh. I can therefore conclude nothing other than that this blackish half of the island is either wooded or watery. If there is anyone else who can find a more fitting explanation, he will certainly do something most welcome both to me and to all who are eager for knowledge.

[Margin: On the whitish rays seen around full moon.]

The whitish, or luminous, rays, however, that present themselves scattered here and there around full moon in the lunar oceans, on the islands and on the mainland, are nothing other, as I reported earlier, than chains of crags and ranges of very high mountains, which at this time have almost the same appearance as our loftier mountains, beset with eternal snow. But that the ranges of the brighter lunar mountains, especially those rising from Sinai Mons, are likewise snowy is scarcely credible. For since no rains are detected there, and the sky stands continually clear (if one may put it so), it is also easy to conclude that no snows at all can be generated on the Moon. That they are seen to be more luminous than others, however,

[Margin: On the Moon there is no rain, nor snow.]

perhaps arises from their matter, colour, roughness and more suitable situation.

CAPUT XXVI.

Chapter XXVI.

DE PLENILUNIIS, ALIISQUE REBUS SCITU DIGNISSIMIS.

On Full Moons, and Other Things Most Worth Knowing.

[Margin: The aspect of full moons always varies.]

It is not hard to grasp that not all full moons, in every year and in every month, show us one and the very same face. The reason is, of course, the varied and diverse librational motion of the disc, which descends both from the Moon's motion in longitude and from its motion in latitude. For just as all the quadratures, and indeed the phases too, are varied, librated and distorted in a remarkable way, chiefly for this reason, so likewise the full moons are changed. For at one time the gap between Palus Mæotis, or Palus Mareotis, and the Moon's limb, and at another a part of it, whether the northern or the southern, is seen narrower, and sometimes, again, wider. It was this reason above all that moved me to present here, for the benefit of students of the stars, two figures of the full moon. The first of them presents the face of the Moon when it stands in Capricorn and near the northern limit (for up to now this has happened at no other time than in summer, around the solstice; and for that reason I have called it the Summer Full Moon [Plenilunium Æſtivum]). The second shows the image of the Moon when it lies in Cancer, near the southern limit; and because this has always been found, up to now, around the winter solstice, it is therefore called the Winter Full Moon [Plenilunium Hybernum]. From these two figures anyone will detect without trouble the greatest and the least libration to be observed at the periphery, and its limits.

[Margin: On the first full moon, observed in Capricorn.]

The first face of the Moon shown here, as its title makes clear, is the one that was observed near Capricorn and the northern limit — near Capricorn, I say, which should be carefully noted. For this observation, in the year of the Christian era 1644 July 19, at 10^{h} in the evening, in the last degree of Capricorn

Diagram. Engraved plate 20: the Summer Full Moon, a fully illuminated lunar disc drawn within a graduated outer ring. The seas are shown in dense cross-hatching, the uplands and mountain ranges in stippling and fine hatching, with many small craters drawn as rings; a large rayed spot stands in the left half of the disc, another rayed spot at the lower centre with long bright streaks running from it up toward the upper left and the upper right, and a small dark star-shaped mark near the right limb. The outer ring is divided into small alternate black and white divisions and numbered every ten divisions from 10 to 360. The caption is engraved in a cursive hand above the disc. No lettering is recorded in the disc.

- Caption, line 1: Summer Full Moon.
- Caption, line 2: Observed
- Caption, line 3: at Danzig.
- Caption, line 4: In the eastern quadrant, near [?] and the northern limit.
- Outer ring: 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330, 340, 350, 360 — ”10” at the top just left of centre, ”360” just right of it, rising anticlockwise.
- Lower left: 20.
- Lower right: Autor Sculpsit [engraved by the author].

and in the third degree of northern latitude, was made; at that time, namely, the Moon had already passed beyond the limit of least libration, since it had already reached the beginning of Aquarius. For that reason the gap between Palus Mæotis and the Moon's limb was also noticed to be somewhat wider than if this full moon had been drawn exactly in the very first degree of Capricorn, and also in the greatest northern latitude. For then each of the two Lacus Hyperborei would not have been as far removed from the limb as is indeed found in this drawing, but would have been seen practically on the periphery itself.

[Margin: On the inclination of this full moon.]

That in this very full moon the spots appear so strongly inclined towards the east, so that Pontus Euxinus appears higher than usual, arises from this: the observation was made in the eastern quadrant, while the ninetieth degree stood in the western. But you ask why I did not show that full moon in the form it would have had when placed near the ninetieth degree. Know, then, that four figures standing near the ninetieth degree, namely O, P, Q, R, had already been represented in this way; for that reason I chose to offer you the Moon placed otherwise as well, that is, nearer the horizon.

Nor is it out of place to ask here, now that it has been understood that the arrangement of the spots, or the whole inclination of the disc, is seen differently

in the eastern quadrant than in the western, whether, then, the face of the Moon, or the position of the spots, with respect to the perpendicular of the ninetieth degree, is not always exactly the same; and also whether the inclination of the rising Moon, placed in any sign and degree of the ecliptic, is moreover at all times not in the least different from the inclination of the setting Moon.

[Margin: The inclination of the Moon varies even at the ninetieth degree.]

First, then, as regards the Moon's position at the ninetieth degree: if you weigh carefully what has been said in many places and many times, and above all in Chapter 18, about the quadratures and their sections, you can easily infer that it is impossible for that position not to vary at any time — bearing in mind, moreover, that the sections of the quadratures, or what is the same thing, the perpendiculars of the ninetieth degree, change continually in differing positions of latitude. But when the Moon is at either limit, its perpendicular runs

as in the figure inserted in Chapter 18, page 329. Around the ascending node, however, it inclines more towards the west — that is, in the upper periphery — while around the descending node it inclines more and more, by several degrees, towards the east. Hence it happens that the disc of the Moon, together with its spots, is seen now one way and now another at the ninetieth degree. How far this variation extends is likewise found from the chapter just mentioned: so much so that the spots keep, relative to the line drawn from the pole of the ecliptic through the centre of the Moon, a disposition that is by no means constant, but variable with every variation of latitude, as experience itself testifies — although Severinus Longomontanus held another opinion, which he set out in Book I of the *Theorica*, page 192, of the *Astronomia Danica*.

[Margin: In the eastern and western quadrant the inclination of the Moon is greater.]

This inclination of the Moon, then, varies a little at the ninetieth degree; but the inclinations at the east and the west are subject to far greater change. In the circle of the ninetieth degree they arise only from the differing position in latitude; at rising and setting, by contrast, they proceed not only from the difference in latitude but also from the longitude. If this is to be understood correctly, you must know that the line carried perpendicularly through the centre and through the orbit of the Moon is in itself (though not with respect to us, and that is where much of the difference lies) always immobile, as I mentioned above. For that reason the Moon, whether it is at rising, at the ninetieth degree, or at setting, nevertheless always intersects the lunar path at right angles. From this it may easily be presumed that the Moon is inclined far otherwise at rising than at setting, and so again conversely, according as the angle between the Moon's orbit and the horizon is more acute or more obtuse.

Further, we have also found that this angle varies greatly, in just the same way as the angle of the east and of the west, to which it is joined by affinity — except that the angle between the Moon's orbit and the horizon is subject to a still greater variation than the angle of the east or of the west. For since the Moon's orbit intersects the ecliptic at two opposite points, so that one half

of it extends more towards the north and higher, the other more towards the south and lower, in this way the angle between the orbit and the horizon, now greater, now smaller,

Diagram. Engraved plate, Fig. S, showing the inclination of the full Moon's disc as seen at Danzig in three cases, each case drawn as one disc "at the ninetieth degree" and a pair of discs "at rising" and "at setting" set on a horizontal line marked "horizon". Every disc is shaded with the spots; each nonagesimal disc carries a vertical diameter, and each rising and setting disc carries a diameter drawn obliquely to the horizon line. The case number and caption of the second and third cases are engraved on the horizon line of the preceding pair and just beneath it. Signed at the foot: "Fig. S." (left) and "Aut. Sculps." (right).

- Top centre: "1." — "The Danzig inclination of the Moon standing near the beginning of Libra and the ascending node."
- First nonagesimal disc: "At the ninetieth degree"; c at the top and g at the bottom of the vertical diameter.
- Pair on the horizon line marked "2.": left disc "At rising", with e and 26. at upper left, f at the left end of the horizon line, a at the centre, b at the right end of the line, c at upper right, g at lower right; right disc "At setting", with e at the top, 8[3 or 5]. [?] at upper right, c at the left end of the line with one further small mark beside it [?], a at the centre, f at the right, g at the bottom. "horizon" on either side of "2.".
- Beneath that line: "The Danzig inclination of the Moon standing near the beginning of Aries and the ascending node."
- Second nonagesimal disc: "At the ninetieth degree"; no letters.
- Pair on the horizon line marked "3": left disc "At rising", 73. at upper left; right disc "At setting", 36. at upper right; "horizon" on either side of "3".
- Beneath that line: "The Danzig inclination of the Moon standing near the beginning of Cancer, [?] and the ascending node."
- Third nonagesimal disc: "At the ninetieth degree"; no letters.
- Bottom pair, horizon line unnumbered: left disc "At rising", 27. 26. at upper left; right disc "At setting", [?] 36. at upper right; "horizon" between them.

becomes, in relation to the angle between the ecliptic and the horizon, especially away from the nodes. Around the southern node this angle is smaller at rising than the angle of the east itself by 5° and some minutes; at setting, by contrast, it is greater than the angle of the west by as many degrees and some minutes. Around the northern node, on the other hand, the angle here between the Moon's orbit and the horizon is at all times greater at rising than the angle of the east by 5° and about 17′, and again at setting smaller by as much; and all the inclinations of the Moon's disc also vary according to this angle. So that the reader eager for knowledge may grasp better what has just been said, and may also survey with his own eyes some inclinations and configurations of the Moon, at rising and at the ninetieth degree as well as at setting, I decided to

set out the various inclinations of the Moon in certain particular cases in the present figure, namely S.

[Margin: Various inclinations of the Moon at Danzig are shown in a figure.]

Beside number 1 three faces of the Moon are seen, showing how it inclines at rising, at the ninetieth degree and at setting, with the Moon standing, that is, in the first degree of Libra, and in the ascending node itself. Under number 2 the configuration, or inclination, of the disc is seen in the same arrangement, when the Moon is in the first degree of Aries, and likewise in the northern node. Near number 3, when the Moon lies in the first degree of Cancer or of Capricorn, and likewise in the northern node.

[Margin: The method of drawing the inclinations is indicated.]

How I drew these inclinations I shall now show. First, we must have ascertained that vertical point, or the perpendicular of the ninetieth degree — namely e, or e g; for, as you have learned, this varies somewhat and librates through about a few degrees, with respect to us and to the ecliptic. Second, for the configuration of the rising Moon it is also required that the angle between the Moon's orbit and the horizon be known. If it cannot be taken from some definite table prepared for this purpose, it has to be computed specially. By what route this is to be set about is plain to the experts; the others, who are little practised in astronomical matters, can learn it from the books on spherics, to which we refer them.

Once this angle has been ascertained — in the present figure at number 1, at rising, the one marked c a b — its complement to a quadrant, or 90°, at the same time also becomes known, namely

a b g. I say, moreover, that the angle e a f is entirely equal to the angle b a g, as its vertical angle; for *angles at a vertex are equal to one another*, by Theorem 8, Proposition 15, of Euclid Book I. This being so, all that is needed is simply to set off the complement of the angle between the orbit and the horizon — on the left, that is, at rising — starting from f and going upwards, so that neither more nor fewer degrees are contained from the vertical point e as far as f than are contained by the said complement. In this case, here at Danzig, when the Moon is in the first degree of Libra and Leo, the eastern angle between the orbit and the horizon is found to be 64° and some minutes besides. (This becomes known without any trouble when the Moon is near the nodes — from the table of the east, that is, and by simple addition or subtraction of the angle between the orbit and the ecliptic and of the angle of the east or of the west, the first of which always equals about 5°.) Its complement to a quadrant therefore comes out as 26°. I mark off an equal amount from f as far as e; this done, the true inclination of the Moon is at once represented.

To find the inclination of the setting Moon one proceeds in exactly the same way, except that in this case we use not the eastern angle between the orbit and the horizon but the western one, from which those 5° are subtracted. Compared with the eastern angle, this western angle is almost always unequal to it, just like the angles of the east or of the west between the horizon and the

ecliptic. In the figure set beside, for the setting Moon at number 1, the angle between the orbit and the horizon, c a b, is found here at Danzig to be about 12°; if you subtract 5 from it, 7 will remain, whose complement to 90°, namely b a g, comes to 83°, and the angle e a f, as its vertical angle, is exactly equal to it. If, then, that complement of the western angle between the horizon and the orbit, namely 83°, is set off from f as far as e on the right, you will at once have the desired inclination.

We followed the same method under numbers 2 and 3, when the Moon is in the first degree of Aries, of Cancer and of Capricorn. From these drawings it can be seen more than sufficiently that with this inclination of the disc matters stand entirely differently at

rising, otherwise again at setting; and no less that in Libra, Aries, Cancer or Capricorn it is always of a different kind. Meanwhile the inclinations vary not only in these three stations alone, but also at every degree and minute of longitude, and the more or the less on account of the motion of the Moon's cusps.

[Margin: The inclinations of the Moon at Danzig at the beginnings of the signs are shown, at rising as well as at setting.]

For the benefit of the students of the stars, I have decided to append in this place too the Danzig inclinations, of the rising as well as of the setting Moon, set at the beginnings of all the signs (with the Moon, that is, near the northern node), and drawn in exactly the way we have described. From them you will certainly perceive, with singular pleasure of mind, the wonderful variation and inclination of the Moon, and also how one degree of the periphery after another successively becomes vertical. From this it is gathered without difficulty that the perpendicular of the ninetieth degree continually raises itself more and more in the eastern quadrant, up to the circle of the ninetieth degree, while in the western quadrant it inclines more and more towards the horizon — on account, namely, of the hourly variation of the angle between the vertical and the Moon's orbit.

Diagram. Engraving set within the text block, in two rows of seven discs of the full Moon, each disc shaded with the spots and crossed by a single diameter; each row's discs stand on a common horizontal line. Each row is headed by an engraved script caption. Upper row: "The configuration or inclination of the rising Moon about the beginnings of the signs and the northern node, on the horizon of Danzig." Lower row: "The configuration or inclination of the setting Moon about the beginnings of the signs and the northern node, on the horizon of Danzig." In the upper row every diameter runs from upper left to lower right, steep in the left-hand disc and growing flatter disc by disc to the right; in the lower row every diameter runs from lower left to upper right, shallow in the left-hand disc and growing steeper to nearly vertical in the right-hand disc. Several discs of the lower row, chiefly the right-hand ones, carry blue and orange tint over the spots. No letters stand on the discs. Signed at the lower right: "Autor Sculpsit" ("The author engraved it").

- Upper row, sign labels over the discs, left to right: ♈ · ♉ ♓ · ♊ ♒ · ♋ and a second sign [?] · ♌ ♐ · ♍ ♏ · ♎.
- Upper row, at the ends of the horizontal line: ”hori” (left), ”zon” (right) — ”horizon”.
- Lower row, sign labels over the discs, left to right: ♈ · ♉ ♓ · ♊ ♒ · ♋ and a second sign [?] · ♌ ♐ · ♍ ♏ · ♎.
- Lower row, at the ends of the horizontal line: ”hori” (left), ”zon” (right).

Do you also wish to establish the inclination of the Moon's disc for any given hour and minute? It is necessary

[Blue backing sheet; not a page of the book.]

Diagram. Full-page engraved plate: a revolving full moon (a volvelle). A separately cut disc, engraved with the full Moon and its spots, turns inside a fixed graduated ring; a red thread is fixed at the centre of the disc and lies across its left half. The engraved script caption above reads: ”The Winter Full Moon [Plenilunium Brumale], observed at Danzig, about the beginning of Cancer and the southern limit.” The fixed outer ring is divided into four quadrants, each numbered every ten degrees from 0 at the horizon to 90 at the top and at the foot. The ring of the inner disc is numbered every ten from 10 to 360 counter-clockwise, 10 at the top and 360 just right of it. Several of the darker spots carry blue and orange tint. Signed at the lower right: ”Autor Sculpſit” (”The author engraved it”). Plate number at the lower left: 21.

- Top of the outer ring, over the 90 mark: C, flanked by ”Punctum” (left) and ”Nonagecimi.” (right) — ”point of the ninetieth degree”.
- Along the outer ring, upper left: ”Quadrans Orientalis.” — ”eastern quadrant”.
- Along the outer ring, upper right: ”Quadrans Occidentalis.” — ”western quadrant”.
- Right, at the 0 mark of the outer ring: B.
- Right, outside the ring, astride the horizontal radial line at the leaf's edge: ”Occi[?]” and ”ſus.” written vertically above and below the line, ”hori” and ”zon” horizontally just above and below it — the first two cut at the edge on this copy (the Toronto copy, imaged with its margin, shows nothing lost after ”hori”); ”hori … zon” gives ”horizon”.
- Outer ring, figures read: upper left 20–80; top 90; upper right 80 down to 10; lower right 10 to 80; foot 90; lower left 80 to 30, then a 2 whose second figure is not settled (2[?]); the lower-left 10 and 0 not visible.
- Inner ring: 10 to 360, every ten.
- Inner ring, between 40 and 30: three small marks, each with a point above it — the descending-node sign ♑, the letter L, and the ascending-node sign ☊ (named as they stand in the orientation of the ring's figures).

therefore, that you first ascertain the angle between the vertical circle and the Moon's orbit for the given time, either from a special table or from a trigonometric calculation. Then, by the method already described, lay off its complement in the eastern quadrant, on the left, from *f* to *e*. In this way you

will have the true inclination for that very time fixed in advance. [Margin: To find the inclination for any given hour.]

From everything we have just said it is more than sufficiently clear that the inclinations of the Moon vary not only with its motion in longitude and latitude, but also with the Moon's differing position relative to the ninetieth degree and the horizon. Nor are they fully accounted for even by these. For the inclinations of the Moon on different horizons turn out extremely different: that is, according to the difference in the elevation of the pole, they are altered more and more, over and above that earlier variation. Furthermore, the lower the elevation of the pole at a place, the greater this inclination becomes (that is, the more the vertical point of the ninetieth degree inclines, of course, towards the horizon, at rising as well as at setting); and conversely, the higher the elevation of the pole at a given place, the smaller this inclination is there. [Margin: The inclination arises from the most diverse causes; hence it is very varied.]

From this it is again clearly evident that the inclination is so varied that it is scarcely possible to determine these often-mentioned inclinations, because of the continual variation of the Moon's longitude, latitude and altitude, and of the elevation of the pole. Nevertheless it would help not a little if anyone, living on any horizon whatever, could set the inclination of the Moon in all the cases described above before his own eyes with the aid of some full moon drawn in advance, with no great labour and indeed at a moment's notice. For this would certainly be a great aid not only in eclipses but in all the other observations of the Moon as well, as will be shown below in its proper place. [Margin: To determine the inclinations correctly is of no small importance.]

And I shall now show that this can be done successfully, without any expenditure of much labour and time, provided the motion of libration is not taken into account, by means of the present *Plenilunium Brumale versatile* [Plenilunio Brumali verſatili] [the shifting full moon], prepared for this purpose. But before we can reach that point, it is above all necessary that you compute for yourself a table of the angles between the vertical circle and the lunar orbit for your own elevation of the pole, [Margin: It is taught how to represent all the inclinations of the Moon, at any place and time, by means of the *Plenilunium versatile*.]

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namely for every single degree of longitude and altitude. If that seems too troublesome to you, it is enough for this purpose to compute it for every ten degrees of longitude only, and for each half-hour, or quarter of an hour. But just as great as the labour of making such a table is, so great is the advantage it brings in return, and so much the more welcome it proves to us when we need it. For if one does not have it to hand, it is certainly much more troublesome to compute the angle first for each inclination.

Once the table has been properly made, then, look up with its help, for the given time and place of the Moon, the angle of the vertical circle and the Moon's orbit; to extract it you will need a double proportional part. When that is done, on the divided outer circle count upward from A, towards C, the

point of the ninetieth degree, as many degrees as the complement of the angle contains — that is, if you want the inclination of the eastern Moon. Next, since this figure has been so prepared that it can be turned round, turn it to the left until one of the three upper points (which are seen between the 30th and 40th degree) touches the last counted degree of the complement of the angle.

Do you ask, though, which of these three points must be attended to here? I answer: if the Moon is at the southern node, you must take the most easterly of all, placed at the 37th degree; the middle one, if it is near the limits; and the western one, seen at the 31st degree, when the Moon is near the northern node.

But if you also want to know the position of the Moon's inclination in the eastern quadrant, count from B towards C, as was done before, as many degrees as the complement of the angle of the vertical and the Moon's orbit holds. Then turn this figure of the Full Moon round to the right, towards the west, until once again one of those three upper points — whichever you need at that time — is set at the last counted degree. When this is done, you plainly have the true inclination corresponding to the given time and place of the Moon. From it you will at once perceive which degree of the periphery stands at the ninetieth degree at that time, and no less which places, valleys and mountains are set in one straight line with the point of the ninetieth degree, C, and the centre of the Moon, which indeed

can be examined accurately with the help of such a silk thread. What use and advantage this may have will be told in its own place.

[Margin: Is the whole hemisphere of the Moon, entirely, illuminated by the Sun at any time whatever?]

Now that I have said enough, I think, about the variation of the Moon's inclination, it will not be out of place to move on to the remaining matters and to some questions concerning the full moon. For the first question is this: does the Sun, at any time, and especially at full moon, illuminate exactly half of the Moon? The answer is no. Yet I by no means deny that *if the luminous sphere is equal to the opaque sphere, half of the opaque sphere is also illuminated by half of the luminous one*, by proposition 45 of Book V of François d'Aguilon's *Optics*; or, as Ibn al-Haytham puts it in his book *On Twilight*, no. 2, and Witelo, book 2, proposition 26, and also Aristarchus of Samos in his book *On the Sizes and Distances of the Sun and Moon*: *If a spherical luminous body illuminates an equal opaque one, it will illuminate a hemisphere.* But since the Sun is far larger than the lunar globe, it therefore also illuminates more than half, by force of proposition 46 of Book V of d'Aguilon's *Optics*: *If the luminous sphere is larger than the opaque one, the larger part will be illuminated by the smaller part of the luminous one*; or, to use the words of Ibn al-Haytham, *On Twilight*, no. 3: *If a spherical luminous body illuminates a smaller opaque one, it will illuminate more than a hemisphere.* This is no less confirmed by Witelo, book 27, and by Aristarchus of Samos in his book *On the Sizes and Distances of the Sun and Moon*.

The limit of the illumination must therefore be a circle, yet one smaller than the greatest circle described on the spherical body of the Moon. This circle of

illumination, however, is not always of the same size; it varies a little according to the Sun's distance from the Moon, and the greater that distance, the smaller the illuminated part of the opaque body. Since, then, this circle is the greatest of all at the time of full moon, it follows by a fixed law that the illuminated part of the full Moon is the smallest of all.

[Margin: The Moon is never less illuminated than when it is full.]

Strictly speaking, these words are equivalent to the ones I shall now set out: the Moon is never less illuminated than when it is full. The common people will scarcely ever believe this, for they cling to the opinion that at full moon the Moon is most flooded with the Sun's brilliance. But in this they stray by the whole sky, not knowing that an opaque spherical body is illuminated less by a larger and more distant luminous spherical body, but by a nearer one — even one of equal size — more. The opticians have demonstrated this amply enough, especially François d'Aguilon in Book V, proposition 48, of his *Optics*, in these words: *A larger luminous spheroid irradiates a larger part of the opaque body from near at hand than from far away.* Witelo confirms this equally, book 2, proposition 23.

Since, then, the Moon at full orb is always as far as possible from the Sun (namely when the Earth is interposed) — farther than before or after opposition, and above all than at the time of conjunction, when the difference is reckoned at about 120 semidiameters — it follows, as I was just saying, that the Moon is never less illuminated than when it is full; and for that reason the circle of illumination is also the smallest of all at that time.

[Margin: How large is the illuminated part of the Moon?]

How large the illuminated part of the Moon really is, when the circle is greatest or smallest, astronomers teach us to find by various methods, given, of course, the distance of each of the two bodies and their diameters. Among others, Erasmus Reinhold, in his *Commentary* on Peuerbach's *Theories*, fol. 165, fixes that part, as far as the circle of illumination, at 189° 45′, so that the Moon is illuminated 9° beyond the half. But the most acute Kepler, in his *Astronomiae Pars Optica*, chapter 6, no. 3, page 231, not only calls this into doubt but also plainly demonstrates that the part of the illuminated circle is much smaller: namely only 180° 31′ 20″ when the Moon is new and in apogee, and the shaded part, the remainder, 179° 28′ 40″; whereas with the Moon in perigee the illuminated arc can be 180° 28′ 12″.

Meanwhile, however, at full moon we do not see this whole part illuminated by the Sun, which is larger than a hemisphere, since the visible diameter of the illuminated lunar body is larger than the space between our two eyes (for then the circle of vision is smaller than a hemisphere), according to proposition 70 of Book IV of Witelo: *If the line joining the centres of the two eyes is smaller than the diameter of a convex sphere, what is seen is less than a hemisphere.* Because of the distance between our eyes and the illuminated body, however, the circle of vision decreases, so that one may then view the larger portion of the illuminated

part of the Moon. D'Aguilon confirms that this is so in proposition 44 of Book V of his *Optics*, in these

[Margin: The less the Moon is illuminated by the Sun, the more of it is seen.]

words: *An external luminous point irradiates a larger part of a more distant sphere than of a nearer one.* From this it is inferred that more of the Moon is seen in apogee, although it is less illuminated by the Sun, whereas in perigee it is more illuminated and less is seen. But the greatest part that is ever seen by us in apogee is always, as I mentioned above, smaller than a hemisphere, just as the part illuminated by the Sun is always larger than a hemisphere. The circles of vision and of illumination that arise from this are equally distant from the circumference of the greater circle, and at the very moment of the truest opposition each circle is about 30′ distant from it on every side. As long, then, as the circle of vision does not yet touch the circle of illumination, so long does the Moon appear exactly and completely full and round.

[Margin: How long can a perfect full moon last?]

From this Witelo and Reinhold concluded that the full Moon can persist for as much as two whole hours, unchanged as regards its decrease, before it appears to decrease, as Kepler reports in the place already cited above.

[Margin: Kepler's opinion on this matter.]

But in the same place, page 237, the author just mentioned entirely opposes this opinion, saying: *no perfect full moon has ever been seen, nor can one be seen; so far is it from true that a single full moon lasts two hours.* Moreover, since what he himself sets out on all these matters in what follows is most noteworthy and by far the most ingenious, I shall add his own words here:

For since the semidiameter of the shadow equals two and a half semidiameters of the Moon, when one semidiameter of the Moon is added, so that the Moon and the shadow, facing each other, may admit a proper space free of shadow, about 64 or 66 scruples will be made up. The Moon must be just as far from the point opposite the Sun, whether in longitude or in latitude, unless it is to graze the shadow. But at so great a distance from opposition, an intersection of the circles of illumination and of vision already takes place, because these touch each other at a distance of 30 scruples between the Moon and the place opposite the Sun. Either, then, the Moon cannot become full because of its northern or southern latitude, or, if it can become full, then as it passes through the moments of opposition it begins to be eclipsed before it becomes full, entering the shadow of the Earth. Unless perhaps a southern parallax comes to the aid of a Moon that stands off to the north, or the reverse.

These things are said as truly as they are acutely, though somewhat obscurely. Their true sense is this: when the opposition of the luminaries happens near the nodes, the Moon's centre is then very close to the ecliptic, in which the centre of the Earth's shadow, whose diameter is about 64 or 65′, also lies at that time. But the Moon, not sooner full and round

completely, is seen than when it stands only 30′ from the point opposite the Sun, or from the centre of the shadow, where those two circles of vision and of

illumination cease to intersect each other any further. But before it reaches that thirtieth minute from the point opposite the Sun, it must already be grazing the shadow, for the shadow's diameter extends to 66′; so the Moon reaches the shadow sooner than it acquires its full light. Again, after opposition, it begins to decrease once more before it emerges from the shadow, for the semidiameter of the shadow is 36′ greater than the distance from the point opposite the Sun to the limit of the intersection of those two circles of vision and illumination.

But if at the time of opposition the Moon has a latitude, either northern or southern, greater than the semidiameter of the shadow, so that it can pass the shadow without touching it, either on the upper side or the lower, even then it would by no means be full on every side. For the latitude would then be much greater than the distance of 30′ already mentioned, and only within that interval does the Moon appear exactly full and round. And the greater the latitude, the more the upper or the lower limb would appear to have decreased. So, strictly speaking, whether the Moon is near the nodes, at the limits, or at the distance between them, it always decreases too soon, before it becomes exactly full. It is therefore impossible that a fully round and true full moon should ever occur, however small that deficient part may be.

[Margin: A perfect full moon is never seen.]

[Margin: Can that deficient part of the full moon be detected by the eye?]

This is what the most distinguished Kepler, by the power of his most happy genius, was able to infer from certain and indubitable reasons, persuaded as he was that the deficient part of the full Moon is so thin that it cannot be seen at all. But I (with the leave of so great a man) disagree with him, since from observations and the experience of the eyes I have learned something quite different: although that deficient part is indeed very slender, as is easily inferred, it is nevertheless at all times sufficiently visible in the Moon opposite the Sun — not, indeed, with the naked eye, but with the help of a long and perfect telescope. As for the disc of the Moon filled with light on every side — a precisely round full moon — I scarcely remember ever, at any time,

having noticed and observed one in such a way that some small particle of light was not still missing on one side or the other, whether upper or lower (although the part was at times very small); hence a notable roughness sometimes showed itself even at the very moment of opposition. Indeed, when the Moon was near the tail or the head of the Dragon, something was generally lacking on the eastern or the western side; near the northern limit, the southern limb was not a little rough; at the southern limit, by contrast, the northern periphery was by no means full and entirely free of unevenness. And the greater or smaller the latitude, the greater or smaller the deficient part was found to be.

I could produce a great many examples and observations of this kind here; but so as not to detain the kind reader with many, I shall present only a few, since some of them have already been partly mentioned in the sixth chapter.

[Margin: First observation.]

1. In the year of the Christian era 1644 April 21, at 11^h in the evening, the fourth before the true opposition, the Moon was not only not yet completely filled with light on its eastern limb, but at the same time was already noticeably rough on the lower, southern side. The reason is that at that time it had a northern latitude of 3½°.

[Margin: Second observation.]

2. In the year 1645 September 5, at 10^h in the evening, 4 before the true opposition, while the eastern limb was again very rough, the upper and lower parts appeared quite round and smooth, because the southern latitude amounted only to about 1½°.

[Margin: Third observation.]

3. In the year 1645 October 5, at the eighth hour in the evening, the sixth after the true full moon, the Moon had decreased not a little, not only on its western side but also on its northern periphery above the Mare hyperboreum. And this was then above all, and most of all, worthy of notice and admiration: although the Moon was already rather lumpy and full of hollows on its western limb, it nevertheless presented on its very eastern periphery the notable and highly conspicuous summit of some very lofty mountain. From this it is clearly evident that on the very limb, by the help of some excellent tube, mountains and valleys plainly

can be observed, as we have already demonstrated earlier in the sixth chapter. That the upper part of the periphery was more than moderately jagged arose from the fact that the Moon's southern latitude at that time was 4½°.

[Margin: Fourth observation.]

4. In the year 1645 June 8, 12^h before the truest moment of opposition, that south-eastern [Euroaustralis] part, from Lacus Mareotis as far as the Montes Dalangueri, was extremely rough and uneven, and by no means full and rounded on every side. At 12^h after the true opposition, namely on June 9, the periphery itself towards the south-west [Notozephyrum], from the Lacus Meridionalis as far as the Palus Mæotis, was likewise very uneven and sinuous; apart from this roughness, however, the whole outer circumference of the Moon was seen in an even sweep, so that this roughness and the deficient part had moved on from the south-eastern part of the limb, through the south, towards the south-west. From this it is certainly concluded that at the time of the true opposition the greatest unevenness of the Moon was visible on the Moon's very limb, the lower and southern one; for at that time the Moon was near the northern limit, so that it could not have happened otherwise than this.

[Margin: Fifth observation.]

5. In the year 1646 April 29, at the ninth hour in the evening, at the very moment of full moon, the Moon's limb was rounded almost on every side, except that only in the more southerly part of the Moon was it noticeably rough and winding; this roughness extended over about 90°.

The reason is that the Moon had at that time acquired a latitude of 5° and had reached the northern limit.

[Margin: According to the differing latitude of the full moons, now this, now another part of the limb is found to be rough.]

From these observations it is certainly and plainly evident that when the full moon occurs near the nodes, the Moon is not entirely full on either the eastern or the western limb, but appears altogether rough and harsh. When the full moon falls at the northern limit, such unevenness is noticed on the southern, that is the lower, side. But if it is observed near the southern limit, then in turn some deficient part of the limb is detected on the upper, northern side; and this roughness is now greater, now smaller, according to the Moon's greater or smaller latitu-

de. Now nothing more remains for me to say on this subject than to illustrate what I have just said with a figure, so that for any beginner in selenography the true reason of this matter may not only be plain to the mind but also be set before the very eyes.

[Margin: Which is made clear by a figure.]

In the present diagram, then, let the line A d c be the ecliptic; c the Sun; d the Earth, or the place of vision; A the Moon placed in the ecliptic, that is, near the nodes; B the Moon standing at the northern limit; and C the Moon at the southern limit. All the lines running from the Sun to the Moon, namely c e and c f, are lines of illumination, and e f is the base of the pyramid of illumination. The lines hastening from our eye d to the Moon are lines of vision, and g h is the base of the pyramid of vision. The part enclosed by the lines of illumination is merely illuminated by the Sun; the part contained by the lines of vision is merely seen by us. At A, with the Moon near the nodes, the bases of the pyramid coincide in one line; for this reason nothing whatever of the Moon's dark hemisphere is seen at that time, and so at that very time its periphery necessarily appears exactly smooth and rounded. Near the limits, however, the bases of the pyramids of illumination and of vision intersect each other, so that it cannot be otherwise than that some small part of the darkened hemisphere, which lies hidden, is presented to us. For this reason, at that time of full moon, the periphery appears, with respect to the eye, not entirely even and round but in part knobbly and rough. Near the northern limit a certain small part is missing

Diagram. An engraved figure inset in the text, on a shaded ground. A horizontal line, labelled "Ecliptica." near its middle, runs from the left to a point c on the right labelled "Sol."; beside c the line is labelled again "Eclipt." [?]. A large arc bows round the left side of the figure. Three small moons stand on the arc: B at the top (inscribed "Luna in Limite Bore⟦o/a⟧", "the Moon at the northern limit"), A on the ecliptic (inscribed "Circa Nodos.", "near the nodes"), and C at the bottom (inscribed "Luna in Limite Auſtrino", "the Moon at the southern limit"). Each moon is a circle with a hatched half and a lighter half. Straight lines run from c to the edges of each moon, and a second fan of lines

runs from the point d, labelled "Terra.", to each moon. Small letters stand at the edges of each moon. The engraver's mark "Aut. Sc." is at the lower right.

- Upper left: "Luna in Limite Bore[[o/a]]" — the Moon at the northern limit
- B: the upper moon; e and g above it; two small letters at its lower edge, f and a cursive letter read as i [?]
- A: the moon on the ecliptic; g and e above it; f and a letter read as h [?] below it
- "Circa … Nodos." — near the nodes (either side of A's circle)
- C: the lower moon; g and e above it; f and h below it
- d, "Terra." — the Earth
- "Ecliptica." — the ecliptic
- c, "Sol.", "Eclipt." [?] — the Sun, on the ecliptic
- Lower left: "Luna in Limite Auſtrino" — the Moon at the southern limit
- Lower right: "Aut. Sc." — engraver's mark

on the lower, that is the southern, side, as can be seen here in the unilluminated part f h. At the southern limit, by contrast, the upper limb does not appear entirely filled with light, as the dark part e, g plainly shows; which was to be demonstrated.

[Margin: Whether the roughness of the full moon is always found to be the same at either limit.]

From this, however, arises a question of no common sort, which I shall briefly unravel before the conclusion of this chapter: namely, whether that roughness, and the deficient part of the periphery, is always seen by us of the same size at the one limit as at the other. I answer that it is not. This, however, will seem astonishing to some. For since the Moon is removed from the ecliptic by an equal distance both at the northern limit and at the southern, except that in the one station it stands as far above the ecliptic as in the other it stands below, why should the deficient part of the southern periphery near the northern limit not also be entirely equal to the other part, that of the northern periphery near the southern limit? That it turns out otherwise, however, comes from the parallax of altitude. For, as we learned in the seventh chapter, by reason of this parallax the Moon is constantly depressed by about a whole degree; so that when the Moon is at the northern limit itself it appears lower by a whole degree, and hence its visible distance from the ecliptic is also made smaller by that much. At the southern limit, likewise, it is depressed from its true place by a whole degree, so that its distance from the ecliptic becomes greater by as much as it had been made smaller in the former case. The difference therefore amounts to two degrees, in that the southern distance from the ecliptic, or latitude, appears greater. For this reason the deficient part of the full moon near the southern limit also necessarily shows itself to us greater than near the northern limit. Moreover, it also follows from this that the Moon, when placed near the nodes, is never seen entirely full and round as regards its upper periphery, since at that time, as was also stressed earlier, it is lower by a whole degree with respect to

us. But when the Moon is found in a northern latitude of one degree, it is then, by the agency of the parallax, placed exactly on the ecliptic; at that time both its upper and its lower limb appear even on every side, full, and round.

CAPUT XXVII.

Chapter 27.

DE LUNAE AB OPPOSITIONE RECENTIS PHASI.

On the phase of the Moon fresh from opposition.

[Margin: Others have held that the Moon does not wane at once on the first day.]

Many very distinguished men, such as François d'Aguilon, Giuseppe Biancani and others, have indeed been of this opinion: that the Moon does not begin to wane at once on the first day, but that the decrease from the exact full moon can be detected scarcely on the second day, indeed not until the third day, after opposition. So the former explicitly writes on pp. 410, 414 and 415 of book 5 of the *Optics*, and the latter on p. 72, near the end of chapter 3 of book 9. They gather this by reasoning from the fact that they hold the breadth between the circles of illumination and of vision, which bound the lines of each, to be very great; and that consequently the Moon can altogether retain the fullness of its light for as long as it takes these two circles to intersect each other.

We can, however, plainly refute this view not only by this phase, since within the space of 30 hours after opposition the Moon had noticeably waned; the contrary is likewise evident from the observations brought forward near the end of the preceding chapter. For, as we have said, and as Kepler has also amply demonstrated, the breadth between the circles of illumination and of vision does not exceed 30′. Therefore the Moon full of light, that is, with its periphery round on every side and evenly bounded, can by no means last for two hours, much less for two or three days. Indeed, it is plainly established from the previous chapter that scarcely any perfect full moon can ever be seen in which its circular outline is not found to be cut off or diminished on one side or the other. But enough of this.

[Margin: In which part of the limb does the Moon begin to wane?]

Now, concerning this phase, when the Moon first begins to wane, the following inquiry will certainly be put: whether the Moon always loses its light on the right side, or not? This question may indeed seem superfluous at first sight, since each and every phase of the waning Moon confirms that its decrease always begins from the west, just as its increase

Diagram. Phase plate 22: a large engraved disc of the Moon, filling most of the leaf, showing the gibbous Moon a little past full, with its maria hatched dark, its craters drawn as rimmed rings, and bright ray systems radiating from several craters (one large rayed crater in the lower middle of the disc, others at the left). The limb is drawn as a continuous circle; no lettering is recorded

in the disc. Above the disc a five-line caption is engraved in a cursive hand; the plate number stands at the lower left and the engraver's mark at the lower right.

- Caption, above the disc: *Phase of the Moon recently past opposition. Observed in the 21st degree of Gemini, around the limit A. Danzig. In the year of Christ 1643, November 26, at 11^h counted from noon; but counted from the opposition, in hour 6 of day [?] 2.*
- Lower left: "22." — the plate number
- Lower right: "Aut. Sculps." — "the author engraved it"

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always ends on the east. Nevertheless, I shall strive to prove the contrary: namely, that the Moon's first decrease does not always take its beginning in the more western part, but in a part of the limb now towards the north, now towards the north-west, now towards the west, now towards the south-west, and now also towards the south. The arguments and proofs of this are for the most part contained in the preceding chapter; but since they were brought forward there for quite another reason and applied to other matters, it will be necessary to repeat them to some extent.

And once the points we stated and demonstrated in the previous chapter are granted — that no true full moon, entirely and on every side round, can ever occur, and that the Moon decreases sooner than it is filled with light on every side — this question, as proposed, seems of itself to collapse altogether. For since there is almost no end to the Moon's increase, there can therefore, properly speaking, also be no beginning of its decrease. But if, at the time of full moon, with the Moon near the nodes, we remove the Earth's shadow, as though it did not exist there in its place, then in such a case the Moon can not only become full on every side, but can also remain for some space of time (however small it may be) with its light full on every side and its outer circuit even, and only afterwards begin its decrease. At that time (and this should be well noted), namely when the Moon is near the nodes, the last illuminated point of the periphery, by which it is completed, will lie plainly in the east, and consequently the first point of the decrease, or its beginning, will lie exactly in the west.

When, however, the Moon is near the southern limit, then, properly speaking, as I was saying a little earlier, neither an end nor a beginning of the waxing or waning Moon is noticed. For as soon as the Moon approaches the point of opposition, that shadowed, rough part of the periphery gradually moves itself towards the north-east [Arctapeliotem]; afterwards, at the time of the true opposition, it proceeds towards the north [Septentrionem], then soon towards the north-west, and finally, little by little, towards the west: so that the remaining dark part of the waxing Moon, while it extends itself in a continuous course across the upper part of the Moon, into the deficient part of the waning Moon

is transformed. Thus, indeed, at the southern limit the beginning of the waning Moon by no means starts in the west, but rather in the part of the limb that faces towards the north-east, or even towards the north.

When, however, at the time of full moon the Moon lingers about the northern limit, the deficient eastern part of the waxing Moon moves first towards the south-east, then through the south towards the south-west, and finally straight towards the west. This is clearly and plainly seen from the observations of the preceding chapter cited above, especially from the fourth, made in the year 1645 on June 8: so that, once again, at that very time of decrease, the beginning of the waning Moon is observed in the south-east or the south, and by no means always in the west; which was to be proved.

CAPUT XXVIII.

Chapter 28.

DE LUNAE DECRESCENTIS PHASI.

On the phase of the waning Moon.

[Margin: On the shadow of the valleys.]

In these waning phases, and especially in the one adjoined, it is seen best and most clearly how, in the valleys, the shadows of the mountains have moved to the opposite side, compared with the shadows of the waxing Moon: for at that time they are seen in the western part of the valleys, but now in the eastern. Moreover, in all the phases before opposition the shadow contracts little by little every day and becomes shorter, and for this reason those valleys then gradually become brighter. After opposition, however, when the Moon wanes, the shadow grows day by day and becomes longer; and so the valleys too appear gradually more shadowed, since the boundary of the dark and the illuminated part comes closer and closer to them at every moment. This is evident in Insula Major, Maris Caspii; for it is certainly much darker today than it was on the immediately preceding day: and so it is with all the pitted and protuberant parts.

And the boundary of this face of the Moon presents itself to view already quite toothed and winding; and in the shadowed part, too, very many brighter small areas present themselves,

Diagram. Phase plate 23: a large engraved disc of the Moon filling most of the leaf, showing the Moon a little past full, with its maria hatched dark, its craters drawn as rimmed rings and pits, and bright ray systems radiating from several craters (a large rayed crater at the lower middle of the disc, with long rays running up and to the left; two rayed craters at the left). Along the right-hand limb, from the upper right round to the lower right, a band inside the circle outline is drawn darker and more heavily hatched. The limb is drawn as a continuous circle; no lettering is recorded in the disc. Above the disc a

five-line caption is engraved in a cursive hand on ruled guide lines; the plate number stands at the lower left and the engraver's mark at the lower right.

- Caption, above the disc: *Phase of the waning Moon. Observed in the 4th degree of Cancer, both around the intermediate points and around limit A. Danzig. In the year of Christ 1643, November 27, at 11^{h} counted from noon; but counted from the opposition, in hour 6 of day 3.*
- Lower left: "23." — the plate number
- Lower right: "Autor Sculpſit." — "the author engraved it"

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especially around Palus Mæotis; and these are an infallible proof that countless very high mountains stand out around the western limb. Above Hyperboreus Lacus Superior, moreover, a very vast bay is seen, extending far into the Moon. It is always seen in this configuration of the Moon, namely when she is in the summer solstitial signs; but in the winter signs it is by no means detected, since at that time the upper part of the Moon is greatly narrowed. From this it also comes about that this bay is carried onto the periphery itself.

[Margin: On the libration motion of this phase.]

As for the libration motion of the disc, it is easy to gather that when the Moon is near the beginning of Cancer and the southern limit, the interval between Palus Mæotis and the periphery is at its widest and most extended; conversely, the interval between Lacus Mareotis and the limb can at that very time never be narrower. This is confirmed not only by this image of the Moon, but also by the Winter Full Moon and by phases 21, 24 and 30 of the Bisected Moon, observed in the first degree of Cancer. And although the space already mentioned is seen at that time to be very thin, nevertheless the lake Miris is never hidden by the Moon's limb, but always remains visible, whatever place of the ecliptic the Moon occupies, provided only that it is lit by the Sun.

Finally, this too must be noted. When this phase falls in Cancer — that is, when the interval at Mæotis is at its widest — the boundary of light and shadow then needs at least two days before it can reach the shores of Palus Mæotis or the mountains lying around it, as is clearly evident here. By contrast, when a similar face of the Moon occurs around Capricorn, that limit of the light is advanced as far in a single day, as is easy to understand: for the interval is then narrower than when the Moon is in Cancer. But in the remaining intermediate signs, the farther the Moon is removed from Capricorn, the more time the boundary needs to reach the shore of Palus Mæotis.

CAPUT XXIX.

Chapter 29.

DE LUNAE GIBBEROSAE DECRESCENTIS PHASI.

On the Phase of the Waning Gibbous Moon.

From the first quadrature up to opposition, the sections of the lit and the shadowed part become, day by day, continually more and more curved and gibbous; in the same way, after opposition, up to the last quadrature, they are seen to grow day by day gradually blunter and straighter. This is entirely and plainly apparent both in the preceding figures and in those that follow.

[Margin: Why Palus Mæotis in this phase seems as if broken off from the mainland.]

Above all, however, the boundary of this figure deserves to be observed carefully, on account of the things of some importance that are visible around it — especially Palus Mæotis, which seems as if broken off from the mainland. Indeed, considering this phenomenon, there is almost occasion to doubt whether Palus Mæotis can be likened to waters at all, on account of those two very deep pits that show themselves in it: something that can certainly never happen in waters, which present a level surface? It is therefore of the utmost necessity that this matter be treated and examined more fully: namely, whether certain valleys or hollows produce this phenomenon, or not. For my part, I seem to myself to be led by no light arguments to think that another explanation underlies it.

For first, it has become more than sufficiently known from the horn-shaped phases, especially the third, that Palus Mæotis is fenced all round — above all on its eastern side — by countless very high mountains. At all times (that is, whenever the boundary approaches its shores) these cast a dark and very dense shadow from themselves onto the opposite side. As a result, the part of the Marsh on which this shadow falls appears dark on every side, just as if it were itself a dark part of the Moon, or certain very deep valleys; and further, near the limit of the light this shadow appears longer than at a more remote distance. That the shadow is not seen spread equally widely everywhere, however, perhaps arises from the differing height of the Montes Alani.

Diagram. Phase plate 24: a large engraved disc of the Moon filling most of the leaf, showing the waning gibbous Moon. Its maria are hatched dark, its craters drawn as rimmed rings and pits, and bright ray systems radiate from several craters (a large rayed crater at the lower left of centre, a smaller rayed crater below and to its left, and a rayed crater at the lower middle with a long ray running to the left). Along the upper right the drawn surface stops short of the circle outline in a jagged, toothed edge, leaving a narrow unlit lune between it and the outline; down the right-hand side a dense column of pits runs close to the limb. No lettering is recorded in the disc. Above the disc a five-line caption is engraved in a cursive hand on ruled guide lines; the plate number stands at the lower left and the engraver's mark at the lower right.

- Caption, above the disc: *Phase of the waning gibbous Moon. Observed in the 20th degree of Cancer. Danzig. In the year of Christ 1643, November 29, at* 1^h *counted from midnight; but counted from the opposition, in hour 7 of day 4.*
- Lower left: "24." — the plate number
- Lower right: "Autor Sculpſit." — "the author engraved it"

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[Margin: What is the reason that spots sometimes appear on the very surface of the Marsh?]

Sometimes, however, with the Moon in such a configuration, rather blackish little spots present themselves on the surface of the marsh; and likewise the part of the boundary [confinium] that bounds the marsh is seen running in no even course — as happened in the year 1644, on December 17, at 1^h a.m. This appearance too arises from the principle just stated. For while the various peaks of the Montes Alani shade the surface of the marsh now in one way, now in another, it can happen that not only does the surface just mentioned appear sprinkled here and there with spots, but the boundary too appears partly winding and uneven. But that small, brightly lit area that is still seen at the edge of the marsh is the island of Alopecia; apart from it, none at all is found in the whole marsh.

Now the great semicircle visible above this marsh is the valley of the Riphæi Montes, in which the peak of a very high mountain reveals itself. Moreover, various darker spots lying close to the section of the light confirm quite clearly that the lunar surface is sprinkled on every side with swellings and hollows.

For the rest, nothing more worth noting occurs in this phase, except that from 18 right up to this very face of the Moon two smaller spots are always seen in the luminous Vallis Ætna. They are a sure sign that either marshy or wooded places exist there, which at other times do not come into view at all; at that time, on the other hand, a fairly brightly lit point shows itself in the middle of that valley, as all the figures without exception attest.

CAPUT XXX.

Chapter 30.

DE LUNAE INCURVATAE DECRESCENTIS PHASI.

On the Phase of the Inward-Curved Waning Moon.

In the figures of the Moon drawn so far after opposition, almost no notable change was detected as regards the mountains and valleys. But in the present one, where the Moon wanes further and the boundary extends farther into it, the valleys present themselves greatly changed in respect of their shadow, and more conspicuous than around opposition.

[Margin: On certain leaden-hued parts.]

Again, the leaden-hued part of the Moon that surrounds Mons Sinai, otherwise called desertum Zin, has from the very first day of its illumination — that is, in all the phases counted from the fifteenth up to this one — always presented one and the same blackish face, although the neighbouring regions are always changed and varied in different ways. What the reason for this is, and what sort of places these are, will become clear very shortly from the figures

that follow: namely, that the place is knobbly and full of hollows, crammed on every side with mountains and cavities. This is attested plainly above all by those three waning quadratures — the thirtieth phase, that is, the thirty-first and the thirty-second — which show that Mons Sinai is entirely surrounded by other, lower mountains.

That places of this kind always appear blacker than others perhaps arises from this: that marshes and woods (or something else of the kind) exist there, which are less suited to reflecting the Sun's rays than other places consisting of a more opaque surface. Very many other places of this sort are found on the Moon besides, and among them not the least place is held by the part that encircles Horminius Mons; for it too is always seen darker, just like the desertum Zin. Among all the remaining places, however, that are leaden-hued beside the waters and blackish beside the mainland, the chief is the one enclosed by Mons Apenninus, Mons Argentarius and Mare Mediterraneum, and furnished with the notable mountains Ligustinus and Montuniates. And this place, not out of countless hills and swellings,

Diagram. Phase plate 25: a large engraved disc of the Moon filling most of the leaf, showing the inward-curved waning Moon. Its maria are hatched dark, its craters drawn as rimmed rings and pits, and bright ray systems radiate from several craters (a large rayed crater left of centre, a smaller rayed crater to its left, and a rayed crater at the lower middle from which a long double ray runs up to the left). On the right the drawn surface stops short of the circle outline: the boundary of the light runs down the right-hand side in an irregular, curving edge, leaving an unlit lune between it and the outline that widens towards the lower right. No lettering is recorded in the disc. Above the disc a five-line caption is engraved in a cursive hand on ruled guide lines; the plate number stands at the lower left and the engraver's mark at the lower right.

- Caption, above the disc: *Phase of the inward-curved waning Moon. Observed in the 13th degree of Pisces, near the ninetieth degree and the descending node. Danzig. In the year of Christ 1644, July 23, at 2^h counted from midnight; but counted from the opposition, in hour 8 of day 4.*
- Lower left: "25." — the plate number
- Lower right: "Autor Sculpſit." — "the author engraved it"

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like the desertum Zin, is formed, but is very marshy. This is presumed from the fact that it does not change in respect of colour, whereas the other parts — namely the desertum Zin and the leaden-hued part that surrounds Horminius Mons — often change their colour, form or shape.

CAPUT XXXI.

Chapter 31.

DE LUNAE IN ORBEM INSINUATAE DECRESCENTIS PHASI.

On the Phase of the Waning Moon Rounding into a Full Circle.

[Margin: On the trines and the limits of their sections.]

Following the custom of the ancients, I have also called these phases observed in the trine aspect "rounding into a full circle" [in Orbem infinuatas]; and the present one is to be counted among them, since it was drawn only four hours before the true aspect. Moreover, just as the sections of the trines of the waxing Moon keep to certain limits and bounds of their own, as was said in Chapter 21, between which all their sections move back and forth, so too is it with the trine boundaries of the waning Moon.

The outermost limit of all, nearest to the centre of the Moon, is seen when the trine falls in Capricorn. For then this section, beginning from the upper part, passes through the Montes Sarmatici, between Mons Carpathes and Peuce, near Promontorium Hippolai; and from there it is carried through Insula Cyanea and Apolonia minor, towards the eastern quarter of Montis Moschi, and through the Montes Uxii and Dalangueri — at the time, that is, of the true aspect. But if the phase were observed some hours after or before, this section would by no means correspond to the limits. Besides, the motion of the cusps too introduces, at a fixed time, a difference and variation, both in the upper and in the lower part of the periphery; yet we do not attend to it here, so that account may be taken of the time.

The other, opposite, outermost limit of the trines — when it is farthest of all from the centre and near the limb — occurs about the beginning of Cancer; at which time the Montes Macrocemni, Sinum Cercinitem, Mons Berosus, Palus Byces, Insula Aëa, Mons Caucasus, and the Montes Coibacarani and Dalangueri are crossed by the section. But if this trine is observed in one sign or another, then its section too is seen nearer to, or farther from, one limit or the other, as shows most clearly in this boundary. For since this trine falls about the beginning of Aries, its section therefore by no means corresponds to those two limits; yet it would rightly proceed by an intermediate path. That it appears somewhat more westerly here, however, comes from the fact that the Moon was observed a full four hours earlier, before the true aspect occurred.

Moreover, concerning this boundary of light and shadow, the point most worth noting is why the two cusps of the illuminated part do not keep a true perpendicular, as they necessarily should; for the inscription clearly indicates that this very phase was drawn about the ninetieth degree. That the Moon here presents a different face in respect of its inclination arises, kind reader, from no other cause than this: while it was being engraved it was by chance moved a little out of place, and so acquired a faulty inclination. So that you may not misinterpret this, I have gladly chosen to warn you of it.

Furthermore, Insula Macra is seen not wholly shadowy and blackish, like the other valleys that lie right on the boundary, but somewhat more livid and

more luminous. Hence, as is easily gathered, it comes about that — while its eastern part, towards the Pontus Euxinus, is not hemmed in by such very high mountains as its western part is — by far the densest and blackest shadow is produced from there.

Below Insula Macra too, on the shore of the Pontus Euxinus, very many luminous small areas and little half-moons are seen; they are clear evidence that innumerable crags and mountains of remarkable height stand in that place.

Diagram. Phase plate 26: a large engraved disc of the Moon filling most of the leaf, showing the waning Moon rounding into a full circle. The maria are hatched dark, the craters drawn as rimmed rings and pits, and bright ray systems radiate from several craters — a large rayed crater left of centre with a smaller rayed crater to its left, and, in the lower half, a crater from which a long double ray runs up to the left. On the right the drawn surface stops short of the circle outline: the boundary of the light runs down the right-hand side in an irregular edge set with crater pits, leaving an unlit lune between it and the outline, narrow at the top and widening towards the lower right. No lettering is recorded in the disc. Above the disc a five-line caption is engraved in a cursive hand on ruled guide lines; the plate number stands at the lower left and the engraver's line at the lower right.

- Caption, above the disc: *Phase of the waning Moon rounding into a full circle. Observed in the 29th degree of Pisces, near the ninetieth degree, the perigee and the descending node. Danzig. In the year of Christ 1644, July 24, at 3^h counted from midnight; but counted from the opposition, in hour 9 of day 5.*
- Lower left: "26." — the plate number
- Lower right: "Autor Sculpſ." — "the author engraved it"

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CAPUT XXXII.

Chapter 32.

DE LUNAE GIBBOSAE DECRESCENTIS PHASI.

On the Phase of the Waning Gibbous Moon.

[Margin: On the apparent diameter of the Moon.]

That the visible diameter of the Moon is always seen by us at its smallest in apogee, its most remote position, and in turn at its largest in perigee, its nearest position, has become known well enough, and more than enough, to all students of celestial matters from Chapter 7. In these lunar figures, however, we have by no means observed this difference between the Moon's visible diameters that arises from its varying distance; nor did we think it worth the effort to keep varying the diameter according to its appearance, bearing in mind that in this way the drawing and the explanation of the figures would become more and more confused. For this reason I much preferred to fix a definite visible diameter in the figures of the phases, and I have always kept

it ever since. Nor did I let myself be troubled by the fact that the Moon near the horizon, rising as well as setting, appears much larger in diameter than in a more elevated position or high in the sky, since this is only an appearance, an illusion of sight. But where this arises from, and what the true reason for it is, deserves to be explained more fully on this occasion.

Two reasons above all present themselves. The first is that there are always denser vapours near the horizon than in a higher position. Therefore, if the Moon is viewed through such thicker exhalations, it necessarily appears larger to us than when it is observed through rarer ones. For rays coming from a rarer medium are refracted in a denser medium, and indeed towards the perpendicular; as a result the angle of vision is made larger, and hence the Moon too appears larger, by virtue of the optical axiom cited in Chapter 2. And the denser these vapours are, the greater the refraction and the widening of the angle become. And therefore, since about the horizons the vapours are thicker and denser when the Moon is in a lower position than when it is in a higher one, it is altogether necessary that its diameter should appear now larger, now smaller, in such varying positions.

The other reason is that this differing appearance of the diameters

[Margin: According to the different degrees of light, the pupil is either narrowed or compressed.]

of the Moon is produced by our pupil. If this is to be understood correctly, one must first know that the pupil, or the opening of the pupil, was not created by Almighty GOD to keep always one and the same size, but was so fashioned that it can, without any effort, now contract itself, now dilate: dilate, that is, when the eye is placed in a brighter medium, but contract when the same eye is placed in a darker one. For unless the different degrees of light varied the form and size of the pupil somewhat, in a certain proportion — so that, namely, much or little light is let into the eye, and above all onto the retinal tunic — that retina would easily take harm and the sight itself would be disturbed, as sometimes happens when too strong or violent a light is incautiously admitted.

[Margin: According to the width of the pupil, the Moon too appears now larger, now smaller.]

This will seem astonishing to some, especially to those who have never observed it and noticed the varying dilation of the eye. But in truth anyone at all can learn it without any trouble by an experiment on his own eye — if, that is, he carefully considers the state of his pupil, first in some dark place and afterwards when placed in a brighter one. So the larger the pupil, the more rays are carried into the eye; and consequently any object must also appear larger than when the opening of the pupil is more compressed and smaller. Therefore, since near the horizons the Moon is seen somewhat dulled on account of the thicker vapours, it necessarily follows that the pupil dilates as the weaker and feebler light comes in, so that the visible disc of the Moon is formed larger on the retinal tunic than when the Moon stands higher, about the meridian, outside the thicker and denser vapours — at which time it is endowed with a

more vivid and clearer light, by which the pupil is contracted more and more — so that it cannot but be that the Moon [near the horizon] appears larger as a result.

Anyone who wants more particulars on this view may read, if he wishes, the first and second Letter *On the Apparent Size of the Sun Low and High* by the most ingenious Pierre Gassendi. On that occasion he also proposes an entirely different and much more correct method of investigating the diameter of the Moon, namely by means of the shadow; and in the same place he likewise shows that the Moon's shadow at night-time is smaller and more slender than

Diagram. Phase plate 27: a large engraved disc of the waning gibbous Moon. The lit part fills the left and lower part of the disc; the boundary of the light runs from near the top of the disc down towards the lower right in a ragged edge set with crater rings, mountain points and small hooked shadows, and the part of the disc beyond it to the right is left unlit inside the circle outline. The maria are hatched dark; a large dark sea fills much of the left half, and a darker patch stands on the boundary just right of the upper centre. Bright rays spread from a large crater left of the lower centre and from a smaller crater to its left, and a long double ray runs up to the left from a crater in the lower centre; a dense field of rimmed craters fills the lower right of the lit part. A small hatched lens-shaped patch stands just inside the outline at the lower right. No lettering is recorded in the disc. Above the disc a five-line caption is engraved in a cursive hand on ruled guide lines; the plate number stands at the lower left and the engraver's line at the lower right.

- Caption, above the disc: *Phase of the Waning Gibbous Moon. Observed in the 17th degree of Virgo or Scorpio [the sign is not settled on this copy], near the ascending node and apogee. Danzig. In the year 1643, December 31, at 3^h counted from midnight; but counted from the opposition, in hour 20 of day 6.*
- Lower left: "27." — the plate number
- Lower right: "Aut. Sculps." — "the author engraved it"

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afterwards at dawn; and that during the dawn it is again larger and broader than later, when the Sun has risen high — although the contrary ought rather to be observed. Where this comes from is likewise explained there by him at length. Among other things he says (which is worth noting): *Although the Moon appears smaller to the eye by day than by night, it nevertheless still appears larger than it really is, by about an eighth part of the diameter; as I have proved by means of the instrument described, which is not subject to as many deceptions as the eye.* Epist. 1, p. 8.

As for the face of the Moon itself, it certainly deserves to be observed by the lovers of the stars themselves with the help of a finely made tube, and to be examined point by point. For about this time, and in the days that follow soon after, a great many things and a very great variation are detected in the Moon, as regards both the mountains and valleys and the boundaries of light

and shadow. Above all, this is very notable: that in this attached figure the section does not bound the Pontus Euxinus evenly, that is, in a uniform course, as by rights it ought, since this place represents an ocean, or water, or, if you prefer, a plain. So far I have had nowhere else to refer this except to various marshy places in the Pontus Euxinus and certain shallows, and besides to the very many islands standing out here and there, which are surely not incapable of producing such a slight roughness on the boundary.

But the greatest roughness of the limit of light, which is noticed below the Pontus Euxinus — namely those very remote cusps — takes its origin from Monte Moscho; and that mountain, because of its remarkable height, as appears from those brightly lit small areas lying in the shaded part, is scarcely the least among the other lunar mountains.

CAPUT XXXIII.

Chapter 33.

DE LUNAE GIBBAE DECRESCENTIS PHASI.

On the Phase of the Waning Gibbous Moon.

It very often happens, indeed, that similar sections — by reason of the course of the spots, in different phases and at different times, of the Moon both waxing and waning —

[Margin: This figure is, as it were, the complement of the ninth.]

are observed. A similar example is before our eyes just now: its boundary is on almost every side equal to the boundary of the ninth, waxing phase; and it is just as if the ninth, just mentioned, were the complement of this present one to a whole hemisphere. That one was drawn on the seventh day after the synod of the luminaries, this one as many days after the true opposition. Now the section of the luminous and shaded part of this one divides Mons Serrorum, Mons Carpathes (which is a very pleasing sight), and passes through the Pontus Euxinus near Sinus Peronticus and Promontorium Archerusia, and that in a straight line; the boundary of that ninth phase, namely, is likewise bounded evenly in this way. There is this difference, however: that Montes Carpathes and Serrorum appear a little larger in this figure than in that ninth one. The reason is that the Moon was at that time in Capricorn, not far from the northern limit, so that it came about that those more westerly and more northerly mountains had moved nearer the periphery, and hence are seen a little smaller and narrower. In this figure, by contrast, they stand farther from the limb and, conversely, are placed nearer the centre; for here the Moon was observed in Leo and near the northern node, and therefore they must appear larger.

Moreover, the section in this phase looks a little blunter than in that one, and the reason is the same: namely, that through the librational motion of the

disc (the Moon being in Leo) the boundary of this one was placed nearer the centre than that of the other, when the Moon was in Capricorn.

[Margin: On the more blackish spots of the Pontus Euxinus.]

Those more blackish spots on the eastern shore of the Pontus Euxinus do indeed present the appearance of valleys and hollows, as we found in phase 24 in the Palus Mæotis; yet no pits exist there. Only the shadow is very black, which is cast into this sea from the lofty mountains (called Catena Mundi) that surround the eastern region of the Pontus; and hence it comes about that the various places in which the shadow ends appear blacker and darker.

Diagram. Phase plate 28: a large engraved disc of the waning gibbous Moon, set in the lower two-thirds of a plate whose upper part carries the caption. The lit part fills the left of the disc; the boundary of the light runs from the top of the disc, a little left of centre, down to the lower right in a ragged edge set with crater rings, mountain points and small hooked shadows, and the part of the disc to the right of it is left unlit inside the circle outline. The maria are hatched dark: a large dark sea fills the upper left and centre of the lit part, with further dark patches below it, and a dark wedge stands against the boundary in the upper centre. Bright rays spread from a large crater in the lower left and from a crater left of centre, and a long double ray runs up to the left from a crater in the lower centre; a dense field of rimmed craters fills the lower right of the lit part. No lettering is recorded in the disc. Above the disc a five-line caption is engraved in a cursive hand on ruled guide lines; the plate number stands at the lower left and the engraver's line at the lower right.

- Caption, above the disc: *Phase of the Waning Gibbous Moon. Observed in the 27th degree of Leo, both near the apogee and near the ascending node. Danzig. In the year of Christ 1643, December 2, at* 4^h *counted from midnight; but counted from the opposition, in hour 11 of day 7.*
- Lower left: "28." — the plate number
- Lower right: "Autor Sculpsit." — "the author engraved it"

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Diagram. Phase plate 29: a large engraved disc of the waning Moon approaching quadrature, set below a five-line caption. The lit part fills the left of the disc; the boundary of the light runs from the top of the disc, left of centre, down to the lower right in a ragged edge set with crater rings, mountain points and small hooked shadows, and the larger part of the disc to the right of it is left unlit inside the circle outline. The maria are hatched dark: a large dark sea fills the upper left and centre of the lit part, a dark wedge stands against the boundary in the upper centre, and further dark patches lie below. Bright rays spread from a large crater in the lower left and from a crater just left of centre, and a long double ray runs up to the left from a crater in the lower centre; a dense field of rimmed craters fills the lower right of the lit part, and a hatched oval patch stands on the boundary at the lower right. No lettering is recorded

in the disc. The caption is engraved in a cursive hand on ruled guide lines; the plate number stands at the lower left and the engraver's line at the lower right.

- Caption, above the disc: *Phase of the Moon Hastening to Quadrature. Observed in the 29th degree of Virgo or Scorpio [the sign is not settled on this copy], near the apogee and the ascending node. Danzig. In the year of Christ 1644, January 1, at 3^h counted from midnight; but counted from the opposition, in hour 20 of day 7.*
- Lower left: "29." — the plate number
- Lower right: "Autor Sculpsit" — "the author engraved it"

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CAPUT XXXIV.

Chapter 34.

DE LUNAE AD QUADRATURAM PROPERANTIS PHASI.

On the Phase of the Moon Hastening to Quadrature.

[Margin: What do those two caverns visible on the section of light mean?]

The present face of the Moon differs little or almost nothing from the preceding one, both as regards the place in the ecliptic in which it was observed and drawn and as regards the librational motion — except that the section comes closer to the centre. For this phase is older by some hours; and for that reason the two mountains, Serrorum and Carpathes, are no longer seen on the boundary of this figure. Instead, in that place there now remain only two very spacious caverns, just as if the mountains already mentioned had been torn out by the roots; indeed, I would scarcely have believed that they had ever existed there, had I not seen them before.

Likewise those darker spots visible in the eastern part of the Pontus Euxinus appear still more blackish and larger. This very plainly confirms what was set out in Chapter 33: namely, that they are nothing other than shadow produced by those loftily raised mountains.

Among the other boundaries of the drawn phases of the waning Moon, however — those of the quadratures excepted — this one is the least curved of all, and conforms itself to a straight line, since it was drawn not very long before the true quadrature: although the Moon very often by no means requires only so much time to reach the straight line, that is, quadrature, as is clear from the phase of the Bisected Moon, which is about five hours younger than this section and is still found to be somewhat gibbous. This arises from various causes, according as the Moon is slow or swift, and lingers in the summer or the winter solstitial signs, and according to how the librational motion is constituted, of which we have spoken already. Next, that the Propontis below the Pontus Euxinus is so rough and rugged arises from this: there the shore first begins

to be lit; and since it is crowded on every side with bays and promontories, it certainly cannot happen otherwise than that an appearance of this kind is seen.

Insula Besbicus shows itself here for the last time, but much more contracted than when the Moon shines with its full orb; on the other hand, in this place it is more blackish than it can be at any time. For the most part, too, all the remaining valleys lying about the boundaries are seen a little smaller and narrower than at the opposition, because around the sections of light and shadow only the floors of the valleys are, as it were, seen; around the full moons, however, the valleys are seen together with the surrounding mountains, which, just like the valleys, are lit equally brightly by the Sun.

CAPUT XXXV.

Chapter 35.

DE QUADRATURIS ULTIMIS.

On the Last Quadratures.

Why the sections of the quadratures, of the Moon both waxing and waning, do not always pass through its true centre in the drawn figures, and why in those same faces of the Moon the lit part is not always equal in size to the dark part, or the dark to the lit — this was resolved by me above, at the beginning of Chapter 18, on the quadratures of the waxing Moon. At the same time it was added that, properly speaking, if the Moon is considered in itself, the sections of the quadratures pass continually through its centre and bisect the Moon, and that at no time is its lit part unequal to the other, dark part, or the dark to the lit, in size and breadth, beyond a nearly quite small portion.

[Margin: The Moon is never exactly bisected.]

From this, above all, it follows that the Moon is never exactly bisected, if you weigh the matter accurately. But how large a part of it is in reality lit, or dark, and whether it is at all times exactly the same or not — this we have resolved to investigate and explain in the present chapter.

First: that the apparent brightness of the Moon in the quadrate aspect is greater than a semicircle is gathered for the most part from Chapter 26. There it was proved concerning the full moons that, since the Sun, as the illuminating body, is larger than the Moon, the illuminated body, its lit part is for that reason also larger than a hemisphere. And this happens not only at the time of full moon, but also always

Diagram. Phase plate 30: a large engraved disc of the waning Bisected Moon, set below a five-line caption. The lit part fills the left half of the disc; the boundary of the light runs from the top of the disc, a little left of centre, down to the bottom in a ragged, nearly straight edge set with crater rings, mountain points and small hooked shadows, and the right half of the disc is left unlit inside the circle outline. The maria are hatched dark: a large dark sea fills the upper left and centre of the lit part, a dark wedge stands against the

boundary at the upper centre, and further dark patches lie below. Bright rays spread from a large crater in the lower left and from a crater left of centre, and a long double ray runs up to the left from a crater in the lower centre; a dense field of large rimmed craters lines the boundary in the lower part of the disc. No lettering is recorded in the disc. The plate number stands at the lower left and the engraver's line at the lower right.

- Caption, above the disc: *Phase of the Waning Bisected Moon. Observed in the 1st degree of Cancer. Danzig. In the year of Christ 1644, September 23, at 3^h counted from midnight; but counted from the opposition, in hour 15 of day 7, namely at the time of the true quadrature.*
- Lower left: "30." — the plate number
- Lower right: "Autor Sculpſit." — "the author engraved it"

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at any other time, whatever face the Moon may present to us. So it also comes about that at the time of the true quadrature (because the circle of illumination then likewise passes beyond the middle, or greatest, circle) the lit part in the halved Moon is somewhat larger than the darkened part, and that the straight line seen in the quadratures does not run quite through the centre. But that this excess of the lit part over a quadrant is not very noticeable, but very small, can be proved from the fact that it amounts to only 15″ (as Kepler likewise confirms in the *Astronomiae Pars Optica*, chapter 6, number 8, page 246). Even so, it does not stay the same at all times, but varies in almost every quadrature, according as the Moon is at apogee or at perigee. At perigee that part is the greatest of all, at apogee the least of all, by force of that optical theorem: *A larger luminous spheroid irradiates a greater part of an opaque body from near at hand than from far off.*

[Margin: Sometimes, for definite reasons, the sections of the quadratures are either advanced or retarded.]

From what we have just set out, namely that in the quadratures the lit part is larger than the shadowed part, this too certainly follows: the boundary of the quadratures of the waxing Moon can reach the centre, or the limit of the section, sooner and earlier than the true quadrature occurs. Again, in the last quadratures, the boundary between the luminous and the shadowed part first advances as far as the centre after the true quadrature. In terms of time this indeed makes little difference (for we have said that the difference between the lit and the shadowed part is more or less small and scarcely noticeable); yet some discrepancy does in truth occur here, whatever its proportion may be.

[Margin: The line bounding the quadrature is straight.]

Further, the writers on optics show that, just as the section of the sickle-shaped or the gibbous Moon is elliptical, so that of the half Moon must necessarily appear straight; and this is clearly seen from these words of Witelo, Book IV, proposition 76: *When the base of the pyramid of vision of a sphere intersects the base of the pyramid of illumination in such a way that their axes contain a right angle,*

their common section is a quarter of the spherical surface; but at a greater distance it appears as a plane surface bounded by one straight line and a semicircle. Kepler, however, is convinced that this line is not quite straight; for he says that he observed in the year 1602

on December 21, that the upper horn of the Moon was a little sharper than the lower. But since he made this observation without a spyglass, I am quite convinced that it was an illusion of sight; for the naked eye is in no way sufficient to discern such very minute things.

[Margin: It is possible for one horn or the other to appear now sharper, now blunter.]

But when we consider the Moon as a mountainous body, crowded on every side with valleys and hills, then not only does this or that horn appear now sharper, now blunter, but the whole line of the section of the Bisected Moon also appears different: on account, namely, of that varied roughness which we have ascertained from all the quadratures. As for the fact that the lower horns mostly appear sharper, this happens because more and higher mountains are found there; and these three phases of the half Moon make this strikingly plain. Yet you will by no means detect that difference except with an eye well armed: so that I seem to myself to conclude rightly from this that Kepler never accurately noticed this phenomenon.

[Margin: It is asked whether the visible illuminated part of the quadrature is greater than a quarter of the Moon.]

Now, since it has been proved that the visible illuminated part of the quadratures is a little greater than the shadowed part, it is rightly asked here in addition whether it also necessarily follows that this illuminated part is always greater than a quarter of the body of the Moon. And at first sight this does indeed seem bound to happen so: for the Sun illuminates more than a hemisphere of the Moon. But if this is weighed on the balance of right reason and carefully considered, it will at once become clear that the illuminated part of the quadrature can never be in any degree greater, nor smaller, than a quarter of the body of the Moon. I do not indeed deny that the circle of illumination exceeds a great circle; but on the other hand, as we have already shown above, the circle of vision is smaller than a hemisphere, by just as much as the circle of illumination is greater. Therefore, by as much as more is seen on the side where the base of illumination, which forms the boundary, lies, by just so much less, in turn, will you see on the other side (namely where the circle of vision bounds the quadrature with a semicircle). So that one may at last safely state that at no time can the illuminated part of the quadratures be either greater or smaller than a quarter of the spherical surface of the Moon.

Diagram. Phase plate 31: a large engraved disc of the Moon at its last quadrature, set below a five-line caption. The whole disc is drawn in outline; the lit part is the lower-left segment, and the boundary of the light runs diagonally across the disc from the upper-left limb down to the lower-right limb, past the centre, in a ragged edge set with crater rings, mountain points and small

hooked shadows. The upper-right part of the disc is left unlit inside the circle outline. The maria are hatched dark: a large dark sea fills the centre of the lit part, with further dark patches near the upper-left limb and in the lower part. A chain of large rimmed craters lines the boundary in its lower half; a crater with bright rays stands in the lower left, a long bright double streak runs across the lower centre, and a dark oval crater lies near the lower-left limb. No lettering is recorded in the disc. The plate number stands at the lower left and the engraver's line at the lower right.

- Caption, above the disc: *Last Quadrature of the Moon. Observed in the 10th degree of [?], near the ascending node and the apogee. Danzig. In the year of Christ 1643, December 3, at 5^h counted from midnight; counted from the true opposition, in hour 12 of day 8; 3 hours before the true quadrature.*
- Lower left: "31." — the plate number
- Lower right: "Autor Sculpſit." — "the author engraved it"

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But the dark part of the Bisected Moon is always smaller than the illuminated part, just as it is also smaller than a quarter of the surface of the spherical Moon. For the circle of vision on the darkened side is likewise smaller than a hemisphere; and the circle of illumination, since it ends beyond the halfway point on the darkened side, must therefore also, by a certain fixed law, be set altogether smaller.

[Margin: The shadowed part of the half Moon that is turned towards us is always smaller than the illuminated part.]

Beyond this, however, yet another question arises about these quadratures: namely, the moment of which phase is more easily recognised? I answer: that of the half Moon. For within the space of a few hours we find its phase much changed, so that around the quadrature its section appears now curved, now straight, now again gibbous, when these changes occur near the centre; but the farther from the centre and the nearer to the periphery they happen, the more slowly they vary. For although the arcs of daily illumination on the surface of the Moon are equal every day, they nonetheless appear larger around the centre than near the periphery, because there they present themselves more directly to the sight, whereas at the limb they are viewed more obliquely. From this it necessarily follows that the sections of illumination around the quadratures change, and are recognised, sooner and faster than at any other time of the remaining phases.

[Margin: The moment of which phase is more easily recognised?]

Now that these small questions have been explained, let us pass on to the three following quadratures drawn here. As for the first, sketched in the year of the Christian era 1644, September 23, at 3^h in the morning — the thirtieth, that is, in order — it is certainly worth noting and considering. For it is one that scarcely comes into view in the completed cycles of many months, since it was observed not only at the time of the true quadrature but also in the very first degree of Cancer and at the southern limit. At that time a boundary is seen that

is more westerly than any that ever appears on the Moon, with respect to the spots and to the motion of libration of the disc; likewise the greatest interval between Mare hyperboreum and the limb of the Moon is shown, as is the least, between Palus Mareotis and the limb. This section passes through the smallest part of the waters, and only through Mare hyperboreum and Propontis (in which Propontis, namely, a little half-moon

[Margin: Phase 30.]

is seen, which is part of Insula Besbicus); and hence this boundary appears very sinuous and winding, as the figure itself confirms. Indeed, in this phase too the more notable mountains are found in their best and most conspicuous form: for they stand very near the line between the luminous and the shadowed part, and in fact partly on the boundary itself — namely, Antilibanus, Olympus and Didymus are seen. This last I rightly called by that Greek name, which means the same as "twin", since it is not only situated at the foot of Mons Sipylus but is also entirely equal to it in shape, position and size, just as if they were twins; and you will certainly scarcely find anywhere on the whole Moon the equal of these valleys.

[Margin: Phase 31.]

The second quadrature of the waning Moon — the thirty-first, that is, in order — was observed at a quite different time and in a different place of the ecliptic; and for that reason it also presents an altogether different face. The section is seen farther towards the east and nearer the centre; the interval between Palus Mareotis and the limb is much wider. For the Moon was sketched in the tenth degree of Virgo, near the northern node, three hours before the quadrature: such a half phase you will find twice a year, as regards the section and the motion of libration. But perhaps you will think this in reply: "What do I hear? Is not the waning quadrature likewise found only once a year in Virgo, just as it is only once in Cancer or Capricorn?" This I certainly do not dispute; but just as the boundary lies at its farthest western limit when the Moon is in Cancer, and at its farthest eastern limit in Capricorn, so too these differ most of all. By contrast, in Aries and Libra no difference is noticed in respect of the interval (especially when the nodes lie in these signs, as happened in these last few years just past, and also in this case). It therefore makes no difference whether the Moon occupies Aries or Libra; for the boundary crosses the same spots, since at these places of the zodiac the motion of libration is the same. Accordingly, since a similar arrangement of this kind occurs twice a year, it cannot possibly be otherwise than that two quadratures equal in every respect come into view.

Secondly, let us suppose that the Moon occupies Gemini, Cancer

Diagram. Phase plate 32: a large engraved disc of the Moon in its waning divided (half) phase, set below a five-line caption. The whole disc is drawn in outline; the lit part occupies the left side, and the boundary of the light runs from the upper limb, a little left of the top, diagonally down to the lower limb right of centre, in a ragged edge set with crater rings, mountain points and

small hooked bright projections standing out into the dark side. The right part of the disc is left unlit inside the circle outline. The maria are hatched dark: a large dark sea fills the upper middle of the lit part, with further dark patches along the left limb. A large crater with a central ring and bright rays stands in the middle of the lit part, and another rayed crater lies near the left limb; a long double streak runs diagonally across the lower centre; a chain of large rimmed craters, one of them dark with an inner ring, lines the lower part of the boundary. A few areas carry faint blue colouring. No lettering is recorded in the disc. The plate number stands at the lower left and the engraver's line at the lower right.

- Caption, above the disc: *Phase of the Waning Divided Moon. Observed in 28 [Capricorn?] [the sign is not settled on this copy], in the intermediate points, not far from the descending node. Danzig. In the year of Christ 1645, April 19, at 4^h counted from midnight; counted from the opposition, in hour 10 of day 9; 3 hours before the true quadrature.*
- Lower left: "32." — the plate number
- Lower right: "Autor Sculpſit." — "the author engraved it"

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or Leo; but that you are able to observe the quadrature not at the very time of the true aspect itself, as often happens, but only once the fourth or fifth hour has passed. Then once again you will find on the Moon a section of the light very nearly the same as if the Moon were placed in Aries or Libra. Further, if the Moon is lingering in Sagittarius, Capricorn or Aquarius, and its quadrature falls only on the following morning, then again the boundary, with respect to the spots, will be almost one and the same; for these sections, as has already been said above, change very quickly. On this basis one may certainly affirm that very many quadratures of this kind, by no means unlike this figure 31, can occur every year.

The case is similar with the quarters of the waxing Moon. For the appearance they present in Aries or Libra, as regards the boundary, they can indeed reproduce in the other signs too, if they are sketched some hours later or earlier relative to the true aspect. There is only this difference: if the Moon is in Cancer, the observation must be made some hours later, but if in Capricorn, some hours earlier; for in this way the limits of the luminous and of the dark part will turn out entirely equal.

Next, between Mons Apenninus, Liguſtinus and Montuniates, two very large hollows are seen, which as it were tear away a great part of Apenninus, so that three notable points are visible around the end of the same mountain. This phenomenon clearly shows that this Apenninus too has very deep valleys, even though at another time you might think that this Apenninus is a rock stretched out in one continuous range, since for the most part it is almost free of shadows and enjoys a very bright light.

But the darker spots visible on the western side of this mountain are nothing but shadows, cast by the summits of the upright mountains of Apenninus.

[Margin: Phase 32.]

Moreover, it is well worth while to weigh this appended quadrature too — namely figure 32 — with care. For it shows a section such as we rarely have the chance to see, since the Moon is observed not only in Capricorn but also near the descending node. From its delineation, both the outermost limit

on the east of the boundaries of the quadratures and the motion of the cusps, or the inclination of the boundary, become quite plain when the Moon is at the southern node. As a result, from this phase and phase 30 the two outermost limits of the sections of the quadratures become very well known; between them the quadratures alternate back and forth over the whole course of the year, apart from the variation of the cusps.

Here the section is partly winding and partly also even, because it extends in part through Mare Mediterraneum. In certain places, however, very striking points are noticed stretching out into the dark part — namely part of Apenninus, and higher up, at Lacus Niger, part of the Alpes — which clearly show that these are not to be counted among the least of the other lunar mountains. Indeed, from this appearance Apenninus will rightly be judged almost the greatest of all; for in all the lunar figures I have drawn, no mountain anywhere appears that stands farther from the illuminated part. For this reason it should also be noted that in the waning quadratures this Apenninus stands as far from the darkened part as its shadow appears to be from the boundary, as the twelfth figure shows quite plainly.

[Margin: Mons Apenninus is almost the highest of all on the Moon.]

Diagram. Phase plate 33: a large engraved disc of the Moon set below a five-line caption. The whole disc is drawn in outline; the lit part occupies the left side, and the boundary of the light runs from the upper limb, left of the top, down and to the right to the lower limb right of centre, in a ragged edge set with crater rings, small hooked bright points and a dark triangular point standing out into the dark side. The right part of the disc is left unlit inside the circle outline. A large hatched dark sea fills the upper and middle part of the lit area, with dark patches along the left limb; a rayed crater stands in the lower left of the dark sea, a long double streak runs diagonally across the lower middle, and a cluster of rimmed craters, one of them dark with ringed walls, lies at the lower boundary. A band of vertical hatching lies along the lower limb, and a few areas on the left limb carry faint blue colouring. No lettering is recorded in the disc. The plate number stands at the lower left and the engraver's line at the lower right.

- Caption, above the disc: *Phase of the Moon recently past the quadrature. Observed in the 20th degree of Leo, not far from the apogee and the ascending node. Danzig. In the year of Christ 1643, November 4, at 5^h counted from midnight; but counted from the opposition, in hour 23 of day 8.*
- Lower left: "33." — the plate number

• Lower right: "Aut. Sculpſ." — "the author engraved it"

Blank page: the back of plate 33, with the plate showing through in mirror image.

CAPUT XXXVI.

Chapter 36.

DE LUNAE à QUADRATURâ RECENTIS PHASI.

On the phase of the Moon fresh from the quadrature.

Just as this phase is the first of all the waning phases that curves, so too in this phase that secondary light shows itself again for the first time in the part turned away from the Sun — that is, in the darkened part of the Moon (which we treated at length in the twelfth chapter of this *Selenographia*). But it is so faint that it can barely be perceived at all. In the following days, however, it grows day by day and becomes brighter, just as in the waxing phases, up to the first quadrature, it decreases from day to day and becomes fainter.

[Margin: The secondary light is seen again in this phase.]

Although the line of this section is curved, yet in the more southern part of the limb it has scarcely advanced as far as the preceding section of the quadrature; in the northern part of the limb, by contrast, it has by no means yet reached that point, but inclines more towards the west [Zephyrum]. For at that time the Moon was in Leo, near the southern node, whereas here it was seen near the northern node. Beyond this, little worth noting occurs here, except that a fairly long cusp of Mons Apenninus is still seen in the dark part of the Moon, and that below Mare Mediterraneum, at its boundary, a semicircle of a different colour presents itself — namely half-black and half-whitish. As far as I can gather for the present, this appearance takes its origin from the summits of the lofty mountains of Tabor, which cast a shadow.

On this same day Mons Sacer, which encircles Sinus Sirbonis at Mare Mediterraneum, begins to be brightly lit, just as if it were covered with snow all over. The Alpes and Atlas minor, which above Mare Mediterraneum encircle Sinus Apollinis above all, present a similar appearance; but in brightness they far surpass Mons Sacer.

CAPUT XXXVII.

DE LUNAE PLUSQUAM LUNATAE PHASI.

Chapter 37. On the Phase of the More-than-Crescent-shaped Moon.

Just as the Moon each day either gradually comes closer to the Sun or moves away from it, so not only its phases, as is easily gathered, but also its spots vary more and more from day to day. As a result, on one day different things appear that were not seen at all on the day before. For example, Mons Porphyrites, which always shows a peculiar colour, as was related above, has kept its form

and shape unchanged from the first day of illumination until now; but now it is seen to be quite altered. For it has lost one upper horn — something generally found to happen on the first or second day immediately after the last quadrature — so that the horn already mentioned then appears nowhere.

[Margin: Mons Porphyrites changes its shape, but not its colour.]

Next, in all the phases, of the waxing as well as of the waning Moon, we saw Sinus Apollinis surrounded by a very brightly lit circle, that is, by exceedingly luminous mountains. But in this thirty-fourth phase the lower half of that luminous circle has now become entirely dark, except that it still shone somewhat on its upper side, as is evident from the figure. Likewise, from the 16th phase until now, Mons Sepher — very large and widely extended, whitish and very bright — was conspicuous like certain most brilliant rays; but in the attached figure only a certain part of it is shown for viewing, and that part much darker than usual.

Again, however, various places are found there (even leaving aside the waters or Seas) that always display the same shape and colour, from the first day of illumination right up to the last. Such are marshy places, reed-beds and thickets, which, as I was just saying, keep their colour at all times. This is likewise made quite plain both from this figure and, above all, from those two Marshes at Sinus Apollinis, and the Island

[Margin: On certain spots that do not change their colour.]

Diagram. Phase plate 34: a large engraved disc of the Moon set below a five-line caption. The whole disc is drawn in outline; the lit part occupies the left side and the lower part of the disc. The boundary of the light runs from the upper limb, left of the top, diagonally down and to the right to the lower right limb, in a ragged edge set with crater rings, small hooked bright points and a dark notch near its lower end. The upper right part of the disc is left unlit inside the circle outline. A broad hatched dark sea runs as an oblique band down along the boundary, with dark patches and lighter bays along the left limb; a rayed crater stands in the middle of the left part, and a dark, many-armed patch lies in the lower middle. The lower part of the lit area is mottled with many small craters and ridges, and a band of hatching lies along the lower limb. A few areas near the left limb carry faint blue colouring. No lettering is recorded in the disc. The plate number stands at the lower left and the engraver's line at the lower right.

- Caption, above the disc: *Phase of the waning more-than-crescent-shaped Moon. Observed in the 2nd degree of Virgo or Scorpio [the sign is not settled on this copy], near the apogee as well as the ascending node. Danzig. In the year of Christ 1643, November 5, at 5½ʰ counted from midnight; but counted from the opposition, in hour 23½ of day 9.*
- Lower left: "34." — the plate number
- Lower right: "Autor Sculpſit." — "the author engraved it"

Blank back of plate 34, with the plate and p. 544 showing through.

Erroris, which lie in Mare Mediterraneum. And this is plain not only from those two, which are always seen neither darker nor brighter, but also from any others that are seen in the Pontus Euxinus and Mare Mediterraneum, as well as in Mare Eoum, and that vary almost not at all in the phases of the Moon, waxing as well as waning. With the Mountains and Valleys, and with the plain, it turns out otherwise: all these parts change from day to day — indeed sometimes hour by hour — now in colour, now in form or shape, as all the figures testify.

From what we have said, therefore, one may argue, hardly frivolously, roughly in this way. Whatever lunar spots are seen to be more livid than the Seas and waters, yet a little darker than the continent, and moreover vary their colour, form or shape in absolutely no phase, but keep it perpetually stable and constant — those can be Marshes, or other things of that kind. But Mare hyperboreum is endowed with a somewhat more vivid light than the other Seas, is besides darker than the continent, and is unchangeable. It follows, therefore, that this Sea too is Marshes, or some such thing not unlike them. Spots of this kind are indeed found elsewhere too, as far as their colours go, but they do not last: rather, they become either darker or brighter, and sometimes even vanish entirely, so that such Spots can in no way be compared with Marshes or reed-beds.

CAPUT XXXVIII.

DE LUNAE LUNATAE DECRESCENTIS PHASI.

Chapter 38. On the Phase of the Crescent-shaped Waning Moon.

This thirty-fifth face of the waning Moon, set beside the text, is the complement to the hemisphere of the fourteenth face of the waxing Moon — the like of which is certainly hardly to be found among the others that chanced to present themselves to us in this way. For the two are entirely equal not only with respect to the motion of libration (since this one was observed in Libra, that one in Aries), but also in their boundary. Just as that boundary is for the most part smooth and only very slightly winding, so this boundary that you see behaves in the same way; for each ends at one and the same place in Mare Mediterraneum. And I scarcely believe that more sections can be seen on the Moon that appear either smoother or of a more uniform course.

Moreover, in both drawings this section crosses Mons Ætna and, as it were, bisects it — with this difference, however, that in this phase nothing at all of Mons Ætna is seen in the shadowed part, whereas in that one almost half of the Mountains presents itself, like a very white semicircle, outside the illuminated part of the Moon. From this it is concluded that the eastern Mountains of Ætna are higher than the more western ones, since they are illuminated while standing farther from the boundary.

[Margin: Whether waning Phases are equal in brightness to waxing ones?]

Furthermore, that this figure — with respect to colour, namely that of Insula Sicilia — is quite like the fourteenth Phase arises from no other cause than that this very Island is, in each phase, removed by an equal distance from the limit of light and shadow; and therefore it enjoys a similar darkness in both. Where this darkening arises from, I think I have already explained well enough in the twentieth chapter.

I cannot, however, pass over this without raising, on this occasion, a small question which, I judge, will not be unwelcome to all students of Selenography: namely, whether the phases of the curved waning Moon (when, that is, they are equal in digits and in similarly clear air

Diagram. Phase plate 35: a large engraved disc of the Moon set below a five-line caption, inside the impression of the plate. The whole disc is drawn in outline, with a second thin arc following the right limb. The lit part is a broad crescent along the left limb and the lower limb, widest at the bottom. The boundary of the light runs from the upper limb, left of the top, in a long concave curve down to the lower right limb, with small hooked bright points and crater rings along it. The rest of the disc, upper right and centre, is left unlit inside the outline. A broad hatched dark sea runs along the boundary, with dark patches and lighter bays toward the left limb; a rayed crater with a dark floor stands in the lower left part of the lit area. The lower part of the crescent is mottled with many small craters and ridges, and a hatched band lies along the lower right limb where the boundary meets it. A few areas near the left limb carry faint blue colouring. No lettering is recorded in the disc. The plate number stands at the lower left and the engraver's line at the lower right.

- Caption, above the disc: *Phase of the waning crescent-shaped Moon. Observed in the 4th degree of Libra, near the apogee and the ascending node. Danzig. In the year of Christ 1643, December 5, at 6½ʰ counted from midnight; but counted from the opposition, in hour 13 of day 10.*
- Lower left: "35." — the plate number
- Lower right: "Aut. Sculpſ." — "the author engraved it"

are observed) always appear to us equally bright and luminous? The answer is no: for no small difference is detected in this respect. This question, however, depends in a way on the one put forward in Chapter 13 of this *Selenographia* concerning the secondary light. For it was asserted there of that light that it can be much brighter in the waning phases than in the waxing ones: partly because in the western part of the Moon there is more land than water; partly because this terrestrial globe of ours, from which the reflection is cast all the way to the Moon, at that time turns the greater part of its continent towards the Moon. Hence it comes about that the secondary light in the sickle-shaped phases before conjunction can appear altogether greater, brighter and stronger than after it.

[Margin: In the waning phases the primary light is much weaker than in the waxing ones.]

On the same foundation I likewise conclude that the primary light of the waning phases is much weaker than that of the waxing ones. I do not wish on this occasion to assert that the Sun's rays differ in their operation from our terrestrial ones; rather, I suppose its light to be uniform — although, if everything were weighed on the balance of right reason, some difference in the rays too, or in the light, could certainly be detected here: namely, by attending to the time when sunspots and a great tract of faculae cling to the very disc of the Sun. At such a time, indeed, a great many solar rays would be withdrawn from the Moon, so that in this respect, in my judgement, the Moon would necessarily be weaker. But in truth, as I was just saying, I shall not attend to this difference of light for the present. I shall point out this one thing only: that the eastern part of the Moon is more filled on every side with oceans and seas than the western, and for that reason they cannot reflect the Sun's rays as strongly as mountains and valleys can, as has already been demonstrated more than sufficiently above. From this it indeed follows that the waning phases, or their primary light, at no time appear anything like so bright and splendid. And that the waning phases possess more water is most plainly evident from the accompanying phase, which for the most part abounds in waters and oceans. Again, if we consider a phase of the waxing Moon equal in digits, whether it was observed in Cancer or in Capricorn (for example, the eighth or ninth

phase) — it is at once quite evident that the greatest part of it consists of continent, mountains and valleys, just as we see that the present phase is well filled with seas and oceans. Therefore the primary light of the waning phases is always seen to be weaker and dimmer than that of the waxing ones, just as the secondary light is found to be livelier and stronger in the former than in the latter.

[Margin: The reason why the secondary light of the Moon is always found brighter in the waning phases.]

Taking this opportunity, I shall point out yet another reason why the secondary light can at all times be stronger and brighter in the waning phases than in the waxing ones: namely, that our pupil contributes no little weight in this matter. For, as was noted in Chapter 32, it can now dilate, now contract, according to whether the medium in which it is engaged is brighter or darker. For since the primary light of the phase of the Moon is a little dimmer than that of the waxing Moon, it certainly follows that, on account of the weaker light, the pupil is necessarily dilated more and more than when we look up at a phase of the waxing Moon that is somewhat more luminous. So it comes about that the larger the pupil is, the more rays of the secondary light are carried to the retina [tunica retina]. Accordingly, since the pupil is wider in observations of the waning Moon, not only do more rays enter the eye through that wider pupil, but in consequence the secondary light also appears to us brighter and stronger. And this is what we undertook to demonstrate.

CAPUT XXXIX.

DE LUNAE CORNUTAE DECRESCENTIS PHASI.

Chapter 39. On the Phase of the Horned Waning Moon.

[Margin: On Insula Cercinna.]

Since (as you will readily notice) this section of the luminous and shadowed parts has come nearer to Insula Cercinna than in the preceding phase, that island too is darker in colour in this figure. Indeed, it here presents almost the appearance of a marsh; yet in fact it is not one, but only in the middle a certain marshy place

Diagram. Phase plate 36: a large engraved disc of the Moon set below a five-line caption. The whole disc is drawn in outline; only a horned crescent along the left limb is lit. The crescent is narrow at the top, where its tip runs along the upper left limb in a ragged edge, and widens downward along the left side, sweeping round the lower limb and tapering to a point at the lower right. The inner edge of the light is ragged and set with small hooked bright points and crater rings. Inside the crescent a broad hatched dark sea runs down the left side, with lighter, partly blue-tinted bays along it, a dark rounded patch near the upper part of the inner edge and a large dark patch at the lower inner edge. The lower part of the crescent is light and stippled, set with many small craters, several larger oval ones and two hatched dark areas along the inner edge near the lower right. The rest of the disc is left unlit inside the circle outline. No lettering is recorded in the disc. The plate number stands at the lower left and the engraver's line at the lower right.

- Caption, above the disc: *Phase of the horned waning Moon. Observed in the 8th degree of [?], near the apogee and the northern limit. Danzig. In the year of Christ 1644, December 24, at 7^h counted from midnight; but counted from the opposition, in hour 13 of day 11.*
- Lower left: "36." — the plate number
- Lower right: "Autor Sculpſit." — "the author engraved it"

Blank back of plate 36, with the plate and the facing text page showing through.

is found, from which a long series of mountains and various arms run out into both Mare Mediterraneum and Mare Eoum. In the other figures these present themselves like whitish rays, but now, owing to the different shadow, they are seen somewhat darker — just as that whole island is too, together with that splendid mountain conspicuous in the middle of that marshy place.

Mons Porphyrites, as we noted, had already lost its upper horn in phase 34, and of that horn nothing appears even up to now. In the remaining part of this mountain, however, a certain cave, or a hollow of no small size, is noticed, which was not seen at all in any of the other faces of the Moon. From this it is presumed that this is not solely a single rock, but rather that there is a continuous series of mountains forming some such valley.

Moreover, this face of the horned Moon serves above all for this purpose: by its means a great many places, mountains and valleys, can be recognized from it (which is otherwise granted by none of the others) — namely those mountains situated below Mare Eoum, Sinus Sirbonis and in the lunar Ægyptus: among others Mons Eos, M. Casius, M. Troicus, M. Ajax, M. Cataractes, etc.

The two very black spots seen in the very upper part of the boundary, near Mare hyperboreum, are parts of Mare Mediterraneum, and especially of Sinus Apollinis. But that in this phase the bay already mentioned as it were adheres to Mare hyperboreum, and then that this sea too is so near the limb that the space between the periphery and the sea just named appears very narrow — this arises from the Moon's having been drawn near the northern limit. In the next preceding phase, by contrast, in which that very space was seen to be much wider, the Moon was lingering near the ascending node, so that it must necessarily be wider, as is evident from the motion of libration.

[Margin: The periphery of this phase appears partly rough.]

Above all, however, what occurs in connection with this face of the Moon as most worth noting, and not unworthy of attention, is that its periphery — which otherwise for the most part appears with an even course — is seen here, at the cusp (namely the southern one, as it appears), bounded by a rather tuberous and sinuous outline; phenomena of this kind

we have, to be sure, very rarely observed. But it has this cause: at that time the Moon was at its greatest northern latitude, and so an appearance of this sort necessarily occurs on the side of the lower limb, as we already pointed out above in chapter 26. And this, indeed, shows clearly once again that on the very periphery of the Moon too, mountains and valleys stand out in abundance.

CAPUT XL.

DE LUNAE CORNIGENAE DECRESCENTIS PHASI.

Chapter 40. On the Phase of the Cornigenæ Waning Moon.

[Margin: On Mons Porphyrites.]

We have pointed out quite often already that Mons Porphyrites, by reason of the aspect, always presented one and the same face in the earlier phases. But now at last, as its setting approaches, it is inconstant and changes its shape from day to day. First, in phase 34, the upper horn was vanishing; second, in figure 36, a certain hollow was noticed in the middle; now in the present one the lower horn too has vanished, and the cavity is much larger. On the left side only some mountains are still seen, in the form of a luminous semicircle, but on the right none are present, and the valley is entirely darkened.

From this one may gather that the mountains situated on the left are higher than those lying on the right. Because of their height, they as it were prevent the Sun's light from being able to reach the remaining, lower mountains opposite; and so it is certainly necessary that for this reason the light flies past. But when the mountains toward the quarter in which the Sun is seen are lower, the Sun's

light goes straight to the mountains opposite, so that at that time the mountains facing the Sun are found bright and luminous on every side. Valleys of this kind, closed on one side by higher mountains than on the other, are found on the Moon in very great numbers besides those already mentioned, as can be seen from the phases of the waxing Moon, especially from the tenth figure — namely Mons Armeniæ, M. Carpathes and M. Serrorum, which are higher on the left side, whereas Mons Ida, conversely, is loftier on the right side.

Diagram. Phase plate 37: a large engraved disc of the Moon set below a five-line caption. The whole disc is drawn in outline; only a horned crescent along the left and lower limb is lit. The crescent begins as a thin sliver at the upper left, widens down the left side and across the bottom of the disc, and tapers to a point near the lower right limb, where a short chain of small crater rings runs along the edge. The inner edge of the light is ragged, with small hooked bright points and tufts standing off it in the dark part. A broad hatched dark sea runs down the left side of the crescent and turns along its lower part, with a few light patches and small dark craters inside it. The lower part of the crescent is light and stippled, set with several rimmed craters, two long oval craters, a dark hollow bounded by a rim at the inner edge near the bottom centre, hatched dark patches along the inner edge, and a hatched dark band along the lower limb. The rest of the disc is left unlit inside the circle outline. No lettering is recorded in the disc. The plate number stands at the lower left and the engraver's line at the lower right.

- Caption, above the disc: *Phase of the horn-bearing waning Moon. Observed in the 26th degree of Virgo or Scorpio [the sign is not settled on this copy], near the ascending node and the apogee. Danzig. In the year of Christ 1643, November 7, at 7^h counted from midnight; but counted from the opposition, in hour 2 of day 12.*
- Lower left: "37." — the plate number
- Lower right: "Autor Sculpfit." — "the author engraved it"

Blank back of plate 37, with the plate and the text of p. 556 showing through.

So the farther from the boundary of light and shadow such a very bright semicircle is seen toward the Sun, the lower are the darker mountains opposite; but the nearer to the boundary something of this kind is seen, the higher they are. It is therefore rightly concluded that the mountains on the right side of Porphyrites are loftier than the more westerly ones of Mons Audus, since the latter stand farther from the section of the shadow than the former.

In the phase set alongside there is, moreover, another appearance as well, which will no doubt put this doubt into some minds: why, namely, the mountains Climax, Casius and Eos are drawn in this figure as if larger than in the preceding one. The reason is this: here they stood nearer the boundary, and so they must appear altogether larger. For the Sun, being lower in those places, bounds the valleys only around the summits of the mountains; but in the preceding phase, where the Sun was higher, it there at the same time darted its rays deeper into the valleys, so that they appear more compressed there than

when they are lit around the summits of the mountains. But it is not pertinent to say more about these matters here.

Further, right at the limit of the light, part of Sinus Sirbonis is still seen. Toward the dark part it is bounded by a straight line, like water; toward the other, luminous part, inward, it is bounded by a brightly lit section of a circle, which represents Mons Sacer. Concerning this mountain, the following seems above all worth considering: that it casts no small shadow onto the Sinus just mentioned, that is, onto the surface of this water, as those rather blackish spots visible at the bright section of the circle clearly indicate. This appearance can indeed be detected from no other phase as distinctly as from this one.

CAPUT XLI.

DE LUNAE FALCATAE DECRESCENTIS PHASI.

Chapter 41. On the Phase of the Sickle-shaped Waning Moon.

Since, then, this phase has waned greatly and is of quite advanced age, and since moreover the section of the luminous and shadowy part is now at last passing through Mare Eoum, not very many things worth noting occur here. For whatever

questions are put about the horn-shaped waxing phases are likewise affirmed or denied of these waning ones too, both as regards the Moon's secondary light and as regards its adventitious light and the increase and decrease of that light. So, kind reader, chiefly to save time, I do not wish to detain you longer, except to add only these few points.

First, you should know that those three bays standing out at the boundary are formed by the valleys of Mons Baronisus, M. Porphyrites and Thambes.

Second, that at the cusps there are seen outstandingly bright and illuminated small areas, which are never noticed so distinctly in the phases fuller in light. Rather, the nearer the Moon is to conjunction and the sharper its horns appear, the more and more these little globes shine out — except on the two days before or after the synod of the luminaries, at which time, as is evident from the first and last phase, they do not appear equally bright.

As for Palus Mareotis, it too is seen somewhat changed here. For on both sides the summits of the loftier mountains surrounding it show themselves (now that it has come nearer to the limit of the light), whereas before they had been noticed only on the right side. This appearance, as I was saying just now, is seen in no other phase except on the last day before conjunction and in the phase verging toward opposition, where that marsh shows an altogether similar face.

Finally, let this too be carefully noted: in observing this phase, with the help of a most excellent tube, I was able to make out moderately well the larger spots of the Moon — that is, the seas — in the dark part of the Moon, which could in no way be done in the Moon's earlier faces. Why it was possible here may be gathered more than sufficiently from what was said in chapter 38.

Diagram. Phase plate 38: a large engraved disc of the Moon set below a five-line caption. The whole disc is drawn in outline; only a sickle-shaped crescent along the left and lower limb is lit. The crescent begins as a thin sliver at the upper left, widens down the left side and across the bottom of the disc, and tapers along the lower right limb, where a short chain of small crater rings runs along the edge. A broad, cross-hatched dark sea fills much of the crescent on the left and lower left, along its inner edge, with a light oval, a light irregular patch and a few small light spots inside it. The lower part of the crescent is light and stippled, set with several rimmed craters, two dark oval craters, a pale outlined oval hollow, and short hatched dark patches; the inner edge of the light is ragged, with two hooked bright arcs and a few small bright points standing off it in the dark part. The rest of the disc is left unlit inside the circle outline. No lettering is recorded in the disc. The plate number stands at the lower left and the engraver's line at the lower right.

- Caption, above the disc: *Phase of the sickle-shaped waning Moon. Observed in the 8th degree of Libra, not far from the apogee and the ascending node. Danzig. In the year of Christ 1643, November 8, at 6½^{h} counted from midnight; but counted from the opposition, in hour ½ of day 13.*
- Lower left: "38." — the plate number
- Lower right: "Autor Sculpſit." — "the author engraved it"

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CAPUT XLII.

Chapter 42.

DE LUNAE CORNICULATAE DECRESCENTIS PHASI.

On the Phase of the Horn-shaped Waning Moon.

In Chapter 14, on the phase of the crescent-shaped Moon, we spoke about the inclinations of the Moon's horns: namely, that the horns are not inclined and varied in quite the same way from day to day — partly because of the Moon's varying distance from the Sun, partly because the Moon is not always observed at the same hour, and partly because it also continually changes its place with respect to the ecliptic. Hence the nearer to the ninetieth degree the phases are drawn, the more upright they are as regards the horns. For it is evident in the horn-shaped phases of the waxing Moon, and likewise in the waning ones — above all in those last four — that the upper horns drew back from the perpendicular more and more from day to day. [Margin: On the inclinations of the Moon's horns.]

Yet there is no reason for anyone to imagine that the inclination of the horns will always be the same at any time whatever (even if the phase were entirely equal both in its digits and in its age). Certainly not — unless it happens by chance that this very phase is found again in that very degree and minute of

longitude and latitude. But if it is caught in another sign and at another latitude, then the inclination, like the angle between the Moon's orbit and the horizon, varies very greatly: it becomes now greater, now smaller — that is, it declines now more, now less from the perpendicular — so that a great variation in the inclination can arise at once, even though the Moon is observed in the very same place with respect to the ninetieth degree, as I reported above.

On this occasion, therefore, it is rightly asked: since, for various reasons, the inclination of the Moon's horns turns out so extremely diverse from day to day, and indeed from hour to hour, can we also state the difference of this inclination in degrees — that is, by how much the horns decline from the vertical point at a given time? We answer: most certainly, as the matter will very shortly become clearer; although to others, perhaps, this will seem plainly impossible, on account, that is, of the great and various changes that occur more and more under each different elevation of the pole. [Margin: Whether we can properly determine the difference of this inclination at any time whatever?]

But to settle this properly would call for long circumlocutions, did not the things said in Chapter 26 about the inclinations of the spots around the full moons come to my aid. Accordingly, since something similar happens in the inclinations both of the horns and of the spots (for they move alike, and in quite the same way, as if in a single body), we can therefore, and with no trouble — above all with the help of the *Plenilunium versatile* — attempt and demonstrate what we wish.

So, my reader, I simply send you to that chapter, so that whatever we discussed there about the inclinations of the spots may above all be read through carefully and weighed in the mind. There you will find, among other things, how, with the help of the rotatable full moon, for any place of the Moon and a given hour, under any elevation of the pole, and by means of the table of the angle between the vertical and the Moon's orbit, you can establish the inclination of the spots and set it before your eyes.

So if you want the Moon's inclination for a certain given time and place of the Moon, you proceed in exactly the same way as if the inclination of the spots were to be investigated. Then draw a straight line through a certain point — namely one of those three that stand on the periphery of the rotatable full moon (the one you will then have used) — and through the centre of the Moon. This done, from the inclination of this line you will at once know the inclination of the Moon's horns as well. For there is no difference at all between the two, except that in the horn-shaped phases the horns do not touch that line at all; nevertheless each cusp will stand equally far from the line just mentioned. [Margin: By what method is the inclination of the horns to be investigated?]

Finally, any reader who is even a little attentive will easily notice this too (even if I say nothing), gathering it from what was said before: it is plainly necessary that the complement of the angle between the vertical and the Moon's orbit be set out in the western quadrant if one wants the inclination of the horns of the waxing phases; whereas if you seek the inclination of the horns

of the waning phases, that angle must be transferred into the eastern quadrant. In this way you will have, for any time whatever, the inclination you want of any future phase, and that under any given elevation, in whatever place of the ecliptic the Moon may be, as regards both longitude and latitude.

Diagram. Phase plate 39: a large engraved disc of the Moon set below a five-line caption. The whole disc is drawn in outline; only a narrow horned crescent along the left and lower limb is lit. The crescent starts as a hair-thin sliver at the upper left, widens slightly down the left side and along the bottom of the disc, and thins again toward the lower right, where a short chain of small bead-like points and rings runs along the limb. Along its inner edge on the left lies a cross-hatched dark band with three small dark round spots; across the bottom the light is stippled and carries several hatched dark patches, two dark oval craters with a third dark crater between them, small rimmed hollows, wavy lines, and a few hooked bright arcs standing off the inner edge into the dark part. The rest of the disc is left unlit inside the circle outline. No lettering is recorded in the disc. The plate number stands at the lower left and the engraver's line at the lower right.

- Caption, above the disc: *Phase of the horn-shaped waning Moon. Observed in the 20th degree of Libra. Danzig. In the year of Christ 1643, November 9, at 6½^{h} counted from midnight; but counted from the opposition, in hour ½ of day 14.*
- Lower left: "39." — the plate number
- Lower right: "Autor Sculpſit." — "the author engraved it"

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CAPUT XLIII.

Chapter 43.

DE ULTIMÂ IN CONJUNCTIONEM PROPENDENTE PHASI.

On the Last Phase, Verging toward Conjunction.

In Chapter 26, with the full moons before us, a number of matters of various kinds were examined — hardly unwelcome ones, I think — and above all these two, to say nothing of the rest: namely, that the Moon is never less illuminated than when it is full; and that no perfect full moon — one bounded, that is, by a periphery smoothed on every side — has ever been seen, or can be seen. Yet these two points concern by no means the full moons only, but the new moons as well, if they are rightly applied.

As for the first: just as the Moon is never bathed in less light than at opposition, so it is never lit by greater light than at conjunction, because at that time it is very close to the body of the Sun — that is, to the larger, luminous body — especially if it is placed in its apogee. We explained the reasons fully enough

in Chapter 26, and to it I refer the reader. [Margin: The Moon is never lit by greater light than at conjunction.]

As regards the second: just as no full moon is ever given that is entirely perfect and round on every side as regards its periphery, so likewise no perfect new moon at all is found, for the same reasons that we set out in the chapter just cited. For when the Moon is only so far from the Sun (on whichever side it may be) that it does not cover any part of the Sun at all, then a certain bright part of it is necessarily presented to us (because at that time the circles of illumination and of vision intersect each other) — and indeed a small portion: on the lower side when the Moon is in the north, but on the upper side when it is southern; before conjunction, that is, on the eastern side, but after conjunction on the western side — just as, at the time of full moon, that roughness of the limb is produced, on which see its proper place. [Margin: No perfect new moon is ever found.]

This present phase, moreover, is one of those which very many people have certainly scarcely ever seen, since it offers itself to be observed only very rarely, as do the first and the last phase: [Margin: This phase is seen very rarely, and why?]

since three things must come together here at once if it is to come into our view. First, it is required that a phase of this kind present itself in the descending signs, and above all in Libra; second, that it have northern latitude and, as we said in Chapter 9, be quick and swift. Since, then, two requirements of this sort were present around this phase too, it came about that I saw it so late before conjunction, and at that time it was still quite well elevated — so much so that I had no doubt at all that on the following day as well, the very day of conjunction, I would see it distinctly. And that would without doubt have happened, had not the gable of one of our churches entirely robbed me of the sight of the Moon. The Moon, as the inscription shows, occupied the second degree of Scorpio and the beginning of the fourth degree of northern latitude; it stood only 15° 40′ from the Sun in longitude, and it was observed in the thirty-second hour before conjunction.

On 1645 November 17 I saw an entirely similar last, waning phase, with the Moon removed only twelve degrees from the Sun, about 27^{h} before conjunction. For the Moon was in the 13th degree of Scorpio, that is, at its greatest northern latitude. Examples of this kind are certainly seen very rarely — both because of cloudy air, and because such a phase can occur only once a year; indeed, it often happens that one can scarcely observe it in the space of many years.

Moreover, the fact that this phase is still thinner than the first arises because, at the very moment of observation, it was nearer by almost 8^{h}, or about 4 degrees of longitude, so that it necessarily could not have appeared otherwise. And so, since it was more slender, no notable roughness was seen on the boundary itself either — although it would nevertheless certainly have been seen to be rough in part, had I viewed the Moon at that time with a very long telescope; but the one I was then using was of only moderate length. The horns, moreover,

were extremely sharp, so that it was a pleasure to look at them. The lower horn was indeed not a little darker than the upper; but to what the reason for this appearance should be referred, I certainly cannot say on this occasion. For the shadow was very faint, so that it could by no means be distinctly and clearly discerned and made out.

Diagram. Phase plate 40: a large engraved disc of the Moon set below a five-line caption. The whole disc is drawn in outline, and only a very thin horned crescent along the left and lower limb is lit. The crescent begins as a hair-thin sliver a little above the middle of the left side, runs down the left limb and round the bottom, and thins out toward the lower right. Along most of its length the lit band is stippled and carries short wavy lines; at about the lower left its inner edge makes a small step, and near the bottom a second step marks where the stippled band gives way to a narrower, darker, hatched sliver that runs on to the right. The rest of the disc is left unlit inside the circle outline. No lettering is recorded in the disc. The plate number stands at the lower left and the engraver's line at the lower right.

- Caption, above the disc: *The old Moon verging toward conjunction. Observed in the 2nd degree of Scorpio or Virgo [the sign is not settled on this copy], on the last day before conjunction. Danzig. In the year of Christ 1643, November 10, at 7^h counted from midnight; but counted from the opposition, in hour 1 of day 15.*
- Lower left: "40." — the plate number
- Lower right: "Aut. Sculpſit." — "the author engraved it"

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CAPUT XLIV.

Chapter 44.

DE UTILITATAE EX FIGURÂ PRIMARIÂ Phaſium & Lunationum redundante; deque obſervationis modo Sectionum diurnarum; & deniqúe quomodo viâ haud vulgari, ex ejuſmodi continuatis Lunationum obſervationibus, motus Librationis Diſci inveſtigari poſſit?

On the usefulness that flows from the Primary Figure of the Phases and Lunations; on the method of observing the daily sections; and finally, how can the libration motion of the disc be investigated by an uncommon route, from continued observations of lunations of this kind?

In the various preceding chapters I have, I believe, said enough about the full moons and the quadratures, and about each and every one of the remaining phases, passing over nothing about them that was worth knowing and observing on either count. In what follows, therefore, we propose to speak above all of

the libration motion of the disc, which we already mentioned in Chapter 8. This is not as though not enough had been said about it there; it is rather so that, by adding more and more further observations of various kinds, we may establish and confirm that motion. And it is quite necessary that what has not yet been sufficiently ascertained should be demonstrated thoroughly, from its foundations. This can best be done from figures of various phases. Up to now, however, it has been possible to sketch the phases without attention to the days, or to the individual months following one another in order; from such figures, perhaps, one is hardly granted to see the Moon's daily increase and decrease as clearly as I should gladly wish. This, I believe, will become plainer from what follows.

[Margin: How observations of lunations are to be set up.]

For this reason, so that everything might turn out more successfully, an entirely new invention, not known at all up to now, came to mind: namely, that we compress an entire lunation into a single figure. From it we ourselves have discovered accurately and properly not only how the libration motion varied from day to day, but also in what way the sections of the Moon's daily illumination were continually changed and varied in the individual months; and above all, from it, the metamorphoses of the quadratures too (as we have already indicated above) and their causes, in this

way we have learned more than enough.

At the outset, then, we constructed this primary figure T of the phases and lunations (as was intimated in Chapter 8). It presents exactly the same face as that great general Selenographic Table of the Phases, except that in this figure the shapes and appearances of all the spots, the larger as well as the smaller, have been drawn in simple and very fine lines. Around the middle we have also indicated the motion of the centre, by points marked there at the beginnings of all the signs. We did not, however, draw any fixed periphery or limb around the figure, lest it fail to suit absolutely every observation, of phases as well as of lunations (for the periphery is movable because of the librational motion). In this primary face of the Moon both the position and the proportion of the spots have been observed and displayed together, as far as my strength allowed — not only of the seas, bays and promontories, but also of all the remaining spots, that is, of the islands, mountains and valleys; for almost the whole of selenography depends on their proportioned commensuration. And unless this figure were properly corrected and free of faults, hardly any usefulness could be hoped for from it. But that the arrangement and position of the spots have been drawn here most accurately, we have, in my judgement, shown sufficiently in the eighth chapter already mentioned.

[Margin: The Primary Figure is most useful.]

First, then, this primary image of the Moon is very useful for drawing any phase whatever; you can set about the drawing in this way. First take the length of the scale shown in the attached figure. With it as a radius you will describe a circle, or periphery, from a definite point, or centre, according to the longitude

and latitude found (provided that the longitude and latitude of the lunar phase you have set yourself to observe or sketch at that time is known beforehand). In this way you will at once have and see not only the breadth of the interval of the Palus Mæotis and the Mareotis, but also the breadth of the northern and southern parts, and the true libration of the disc. After that you will only need to draw the boundary through those very spots that are visible at the Moon's section; and then likewise the valleys and mountains, in the same way,

Diagram. Figure T, the Primary Figure of the Phases and Lunations: an engraved outline drawing of the whole face of the Moon, with every spot drawn in fine single outlines and no shading except a few small hatched marks. No circle is drawn round the limb; the disc is defined only by its spots. Along the left side runs a curved band of outlined regions dotted with small rings. Left of centre stands a large round area containing a hexagon and several rings, from which straight double lines radiate outward and upward; a smaller rayed spot stands to its left. A long curved double line sweeps across the upper centre, and to its upper right a triangle of straight lines rises toward the top. In the lower half a long straight double line runs diagonally down from the upper left to a ringed spot near the bottom centre, from which a curved double line runs off to the right. The rest of the disc is filled with outlined seas, bays and chains of small circles and ovals, scattered more thinly beyond the bottom edge. Apart from a small group below and right of the centre — small signs joined by lines, with the words *Aust.* and *Boreal.*, not settled as engraved or added later — the disc carries no letters or names. Two engraved scales run beneath it.

- Above the disc, the title: *Figura Primaria Phasium et Lunationum.* — "The Primary Figure of the Phases and Lunations."
- Lower left: *Fig. T.* — "Figure T."
- Lower right: *Aut. Sculps.* — "The author engraved it."
- Left scale, headed *Semidiameter Lunæ.* — "Semidiameter of the Moon", divided 10, 20, 30, 40, 50, 60, 70, 80, 90, 100; the first division is cut into small subdivisions.
- Right scale, headed *Digiti Ecliptici.* — "Ecliptic digits", divided 1, 2, 3, 4, 5, 6.

Diagram. The General Figure of the Full Moons: an engraved outline drawing of the whole face of the Moon on a plate sheet laid over the page, drawn like the Primary Figure in fine single outlines, with no circle drawn round the limb, so that the disc is defined only by its spots. A broad band of outlined regions sown with small rings runs round the left and upper edge. Left of centre lies a large round area holding a small hexagon and several rings, from which straight double lines radiate upward; to its left a smaller spot sends out rays in all directions. A long curved double line sweeps from the centre up toward the top, and at the upper right a triangle of straight lines rises toward the edge. In the lower half a long straight double line runs diagonally down from the upper left to a ringed spot near the bottom centre; from that spot a curved line set with a row of small arcs runs off to the right, short straight

strokes radiate below it, and a long single curve sweeps away to the lower right. The rest of the disc is filled with outlined seas, bays, chains of small circles and ovals, and a few small hatched marks. Apart from a small group below and right of the centre — small signs joined by lines, with the words *Aust.* and *Boreal.*, not settled as engraved or added later — the disc carries no letters or names. Two engraved scales run beneath it.

- Above the disc, the title: *Figura Pleniluniorum Generalis.* — "The General Figure of the Full Moons."
- Lower left: *Fig. T.t.* — "Figure T.t."
- Lower right: *Aut. Sculps.* — "The author engraved it."
- Left scale, headed *Semidiameter Lunæ.* — "Semidiameter of the Moon", divided 10, 20, 30, 40, 50, 60, 70, 80, 90, 100; the first division is cut into small subdivisions.
- Right scale, headed *Digiti Ecliptici.* — "Ecliptic digits", divided 1, 2, 3, 4, 5, 6.

to shade them in to match the face of the Moon. In this way you will complete any phase whatever in its entirety. This can certainly be done with no great trouble, since the distance and proportion of the spots have already been drawn in lightly in this primary figure, to lighten the labour. But to sketch any phase somewhat more accurately without the help of this figure — especially if someone less practised should wish to attempt it — this is the toil, this the labour, as all who have set their hand to the task will readily admit.

And secondly, this archetype T can also be applied with good results to various other observations: for example, to the occultations of fixed stars and planets that come about through the Moon, and above all to lunar eclipses. These, however, are carried out no less well — indeed equally well and accurately, and, what is more, more conveniently — by means of the other figure, the General Figure of the Full Moons, shown here on the reverse side of the preceding diagram T. The only difference between the two figures is this: the former presents all the spots that exist on the Moon and become visible little by little through the phases, while the latter shows the face of the Moon and its spots only as we see them at the time of opposition, and as you see them sketched in the full moon, both in the larger P and in the smaller O. Since, then, with the help of this figure, lovers of the stars who are less skilled can more conveniently tell the lunar spots apart from one another at the time of an eclipse, this General Figure of the Full Moons will perhaps please them more than the other. But we shall speak of this more fully below, when a suitable place offers itself again. For now we shall show only how, with the aid of the general figure of the phases, the sections of the Moon's daily illumination, and likewise the whole lunation, should be observed; for from such observation a very great benefit can come to us, as will become clear from what follows.

[Margin: The method of setting up observations of lunations.]

These observations of lunations, then, should be undertaken as follows. First, it is necessary to have at hand a copy of that primary figure which you have

seen. You must therefore either draw such a figure yourself, following the figure intended expressly for this work (which you will find toward the end of our *Selenographia*), or, if

you would avoid the labour of drawing it — which is indeed completed only with great tedium and no small expenditure of time, as I could show without difficulty, were it not that, to spare time, I gladly pass it over — you can, if you please, obtain as many images of this primary figure as you need, say 50 or 100, fewer or more, either from me myself or from the booksellers who sell the *Selenographia*, at the very small price at which they are sold. How greatly these images will serve you, to say nothing of the time they save, you will learn hereafter. But take careful heed that you are not deceived by copies engraved on copper a second time by others: for it is impossible for another figure, equally correct, to be engraved after this printed figure of mine, because of the expansion and contraction of the paper. Take care, that is, that in place of my archetypes, which accurately show the primary figure engraved on copper by myself as far as it could be done, counterfeits are not passed off on you.

When you have such a figure at hand, and are busy observing a lunation — of the waxing Moon, for example — first look up in the ephemerides the longitude and latitude of the Moon at the time of the new moon. Then, from the centre corresponding to that motion, draw the Moon's periphery with a radius measured by the length of the scale; and so, by one and the same effort, you will have the libration motion that is to be noted at the time of the conjunction. After this, find the same motion of the Moon as it is at the time of the quadrature; when it is found, describe the limb belonging to the quadrature in the way we have described. Finally, make sure you know the Moon's longitude and latitude when it is full, and with the help of both, draw the lunar periphery. For in this way, with the help of these three circles, you will learn without any trouble whether that librational motion increases or decreases, and likewise whether the sections ascend or descend; and it will become no less apparent whether the observations of the daily libration, especially around the quadrature and the full moon, agree very closely with the sections so drawn and the intervals so described.

Each section, indeed, requires its own periphery, since the motion of the libration and of the centre varies continually; and

so, as many sections as are described, so many limbs would rightly have to be drawn. But then these peripheries would be thrown into great confusion. For this reason I have made it my practice to sketch only the three limbs mentioned above — except that we have nonetheless drawn the sections in the lunation figures longer or shorter in the upper or the lower part, according to their true appearance; and this is plain in the observations that follow.

With these three limbs properly set up, observe the Moon diligently from day to day, as the clearness of the sky allows, and after each interval of twenty-four hours, if it can be done, describe the section of light and shadow according to the Moon's true boundary [confinium]. You will achieve these sections

accurately and with very little trouble if you have first come to know each and every one of the Moon's spots properly and correctly, and have fixed them firmly in your imagination. Otherwise, unless you have made them familiar to yourself by much practice and frequent inspection, everything here will seem impossible to you. Whoever has a mind to undertake such observations, therefore, must have thoroughly studied the face of the Full Moon and the general Selenographic Table of the Phases, and must hold the names of all the Moon's places in memory; otherwise the labour and the effort will be in vain. The sections, likewise, should be continued on each successive day up to the full moon. If you do this, you will have the whole lunation brought together exactly into a single figure. From it you will perceive not only the Moon's wonderful reciprocation but also an admirable alternation of the sections, so that very rarely indeed is one lunation entirely similar to another in every part — something gathered without difficulty from the very motion of the Moon. It will also become apparent day by day, from the cycles of such observations, how the lunar valleys turn now darker, now brighter, now larger, now smaller; and, besides, how that sudden change of the boundaries behaves by reason of the roughness, and a great many other things of this kind, about which more will be said hereafter.

[Margin: What may be hoped for from observations of lunations?]

Indeed, I have no doubt that from accurate and continuous observations of lunations (if, in different regions, men skilled in these arts, with the help of the most excellent spyglasses

were to set them up and keep them going), much greater things than we now understand or even imagine will in time be found and brought to light. Indeed, had I myself not seized on this method of observing right at the outset, and kept it up every day, whenever the sky was very clear, for several years, I would certainly not have carried the primary figure and all the remaining phases as far as I have; nor, for that matter, would I have tracked down the libration motion of the disc, in longitude as well as in latitude, nor the motion of the cusps, of the quadratures and of the other phases; and much less the inclination of the spots and of the Moon's horns — to say nothing of a great many other things hitherto unknown to me, which at length, thanks to this unremitting effort, I have learned thoroughly and come to perceive with the greatest pleasure, not to say profit.

If only we always had a favourable sky in these northern regions! These observations of lunations would certainly be carried out far more easily and with less labour. But since, especially in autumn and winter, more cloudy days than clear and unclouded ones present themselves here, a great deal of trouble arises at such times if we try to complete and represent a whole lunation with each and every one of its daily sections. Sometimes four or more lunations, of the waxing Moon as well as of the waning, are begun, of which scarcely a single one is brought to its end. On one day it is granted to draw the section; then on the second or third day this is prevented by the cloudy air. I have

certainly observed a great many incomplete lunations of this kind, which I did not think at all worth the trouble of reporting here. I shall present only those in which at least the greater part has been carried through, since greater profit, too, is to be had from them. But if these observations were undertaken in Egypt, where an almost unbroken clearness of sky shines, then certainly many more lunations altogether would be obtained in the space of one year than in these regions within four or five years; and what is more, it would be possible to investigate greater and much more certain things. Besides, the frequent disruption of the observations makes people exceedingly weary. For it very

often happens, when we hope that some notable quadrature or any other phase is imminent, that suddenly, against all hope, the sky is completely veiled with clouds on every side; so that in this way the hope of a whole year is lost, since some phases occur only once a year. But enough of this. I now pass to the observations that I myself have drawn from the sky. On this occasion I shall explain all those things that are either obscure in themselves or not yet sufficiently unravelled above; and above all I shall establish more and more firmly the libration motion of the disc, and the motion of the progressions and retrogressions of the quadratures.

CAPUT LXV.

Chapter LXV [recte: XLV].

LUNATIO LUNAE CRESCENTIS obſervata, GEDANI, Anno Chriſti 1644. Menſe Aprili.

The Lunation of the Waxing Moon, observed at Danzig in the year of Christ 1644, in the month of April.

The conjunction of the luminaries in the following scheme V fell in the 18th degree of Aries, at which time the Moon's latitude was found to be 2° 41′ — namely on April 7, at 4^{h} 20^{m} in the morning.

[Margin: Waxing lunation I.]

A. Observed in the 13th degree of Taurus, at 4° 17′ south latitude, not far from perigee and the limit A. On April 8, at 8^{h} counted from noon, 8; but counted from the conjunction, in hour 16 of day 2.

B. Observed in the 28th degree of Taurus, at 4° 57′ south latitude, not far from perigee; on April 9, at 8^{h} counted from noon, 8; but counted from the conjunction, in hour 16 of day 3.

C. Observed in the 12th degree of Gemini, at 5° 8′ of southern latitude, that is, around the limit: on April 10, at 8^{h} counted from noon; but counted from the conjunction, in hour 16 of day 4.

D. Observed in the 26th degree of Gemini, at 5° 4′ south latitude: on April 11, at 9^h counted from noon; but counted from the conjunction, in hour 17 of day 5.

E. Observed in the 10th degree of Cancer, at 4° 43′ south latitude, not far from the southern limit, at the intermediate distance; on April 12, at 9^h counted from noon; but counted from the conjunction, in hour 17 of day 6.

F. The first quadrature, otherwise called by me the Vernal, observed in the 23rd degree of Cancer, at 4° 7′ south latitude, around the intermediate points and the limit; on April 13, at 9^h counted from noon; but counted from the conjunction, in hour 7 of day 7, that is, 2 hours before the true quadrature.

G. Observed in the 6th degree of Leo, at 3° 19′ south latitude. On April 14, at 9^h counted from noon; but counted from the conjunction, in hour 17 of day 9.

H. Observed in the 18th degree of Leo, at 2° 27′ south latitude. On April 15, at 9^h counted from noon; but counted from the conjunction, in hour 17 of day 9.

I. Observed in the 30th degree of Leo, at 1° 26′ south latitude, not far from the northern node: on April 16, at 9^h counted from noon; but counted from the conjunction, in hour 17 of day 10.

K. Observed in the 12th degree of Virgo, at 0° 23′ south latitude, around the northern node: on April 17, at 9^h from noon; but counted from the conjunction, in hour 17 of day 11.

L. Observed in the 24th degree of Virgo, at 0° 41′ south latitude: on April 18, at 9^h counted from noon; but counted from the conjunction, in hour 18 of day 12.

M. Observed in the 6th degree of Libra, at 1° 44′ north latitude: on April 19, at 9^h counted from noon; but counted from the conjunction, in hour 17 of day 13.

N. Observed in the 18th degree of Libra, at 2° 41′ north latitude, around apogee; on April 20, at 10^h counted from noon; but counted from the conjunction, in hour 18 of day 14.

The full moon, observed in the 30th degree of Libra, at 3° 33′ north latitude, not far from apogee; on April 21, at 11^h counted from noon; but counted from the conjunction, in hour 19 of day 15, 4 hours before the true opposition, which occurred in the 3rd degree of Scorpio at 3° 43′ north latitude, on April 22, at 3^h 41^m in the morning.

1. Concerning these sections of illumination, this above all should be well noted: that immediately from the new moon the right-hand interval toward Palus Mæotis and the periphery grew daily, namely up to April 12 and section E. The Moon was then in the 10th degree of Cancer, near the southern limit. Afterwards, however, that space decreased from day to day and became narrower. But the interval toward Palus Mareotis, toward the left, grew by so much space right up to the full moon; at

that time the right-hand space was much more compressed, as was the hyperborean region too: for the Moon was then lingering near the beginning of Scorpio.

[Margin: The full moon was not round on every side.]

2. The full moon appeared to us, on the more southerly part of its periphery, with a tract not entirely even but fairly rough and rugged. The reason is that the Moon then had a latitude of 4°.

Diagram. Engraved plate of the first waxing lunation: a full disc of the Moon with its spots drawn in outline, crossed from top to bottom by the successive curved boundaries of illumination, each boundary marked by a capital letter set in a row across the middle of the disc. Engraved title above the disc, *Waxing Lunation*, with "I." [or "1."?] beneath it; at the lower left "fig V." (*figure V*), at the lower right "Aut. Sculps." (*the author engraved it*). Tiny marks stand at the right and lower left limbs; they are not read as letters.

- Title (top centre): Waxing Lunation
- Numeral (below title): I. [or 1.?]
- Row across the middle, left to right: N, M, L, K, I, H, G, F, E, D, C, B, A — the boundaries of the lettered entries
- Lower left: fig V. — figure V
- Lower right: Aut. Sculps. — the author engraved it

Diagram. Engraved plate of the second waxing lunation: a full disc of the Moon with its spots drawn in outline, crossed from top to bottom by the successive curved boundaries of illumination, with capital letters set in a row across the middle of the disc. Engraved title above the disc, *Waxing Lunation*, with "2." beneath it; at the lower left "Fig. W." (*figure W*), at the lower right "Aut. Sc." (*the author engraved it*).

- Title (top centre): Waxing Lunation
- Numeral (below title): 2.
- Row across the middle, left to right: K, I, H, F, E, D, C, B, A
- Lower left: Fig. W. — figure W
- Lower right: Aut. Sc. — the author engraved it

[Margin: This quadrature is very noteworthy.]

3. Since the quadrature of this first lunation was observed not only in Cancer but also near the southern limit, the section too therefore tends very far toward the west, so that, as regards the spots, it can never appear more westerly. For this reason this section should be carefully attended to, as should all phases in which the interval of libration toward Palus Mæotis is seen as wide as in this one. For I want you to know, kind reader, that you will not detect so wide a space in any phases of the waxing Moon, let alone in quadratures, within a span of 14 or 15 years — phases, that is, in which the Moon will stand at once in Cancer and at once at the southern limit. But from the beginning of the year 1660 up to 1663 that space will again be seen just as wide, while the Moon is in Cancer; then from the year 1664 it will again gradually decrease with the passage of time, as

will also happen in the years 1647, 48 and 49. Hence it is most certain that in these next years, in no phases with the Moon in Cancer, will such a widened interval be seen between Palus Mæotis and the limb as the horizontal limb of the Moon in Cancer indeed shows in my large figures of the full moons and in some other phases. You should certainly not wonder so much at this, however: for the Moon, placed in Cancer, will never again occupy the southern limit before the year 1660. This above all should be well noted, for this reason: so that hereafter, when this space is seen a little narrower, you do not impute it to my carelessness.

CAPUT LXVI.

Chapter LXVI [recte: XLVI].

LUNATIO LUNAE CRESCENTIS OBSERVATA, GEDANI, Anno Chriſti 1644. Menſe Majo.

The Lunation of the Waxing Moon, observed at Danzig in the year of Christ 1644, in the month of May.

[Margin: Waxing lunation II.]

The conjunction of the luminaries in scheme W occurred at 1° 29′ of Taurus, at 3° 38′ south latitude: on May 6, at 0^h 29^m after noon.

A. Observed in the 18th degree of Cancer, at 4° 8′ south latitude, at the intermediate points; on May 10, at 9^h counted from noon; but counted from the conjunction, in hour 9 of day 5.

B. Observed in the 3rd degree of Leo, at 3° 32′ south latitude, at the intermediate distance: on May 11, at 10^h counted from noon; but counted from the conjunction, in hour 10 of day 6.

C. Observed in the 15th degree of Leo, at 2° 30′ south latitude: on May 12, at 9^h counted from noon; but counted from the conjunction, in hour 9 of day 7.

D. The quadrature, observed in the 26th degree of Leo, at 1° 43′ south latitude, not far from the northern node; on May 13, at 8^h counted from noon; counted from the conjunction, in hour 8 of day 8.

E. Observed in the 9th degree of Virgo, at 0° 33′ of southern latitude, namely around the northern node: on May 14, at 9^h counted from noon; counted from the conjunction, in hour 9 of day 9.

F. Observed in the 21st degree of Virgo, at 0° 36′ north latitude. On May 15, at 10^h counted from noon, and, counted from the conjunction, in hour 10 of day 10. On the 16th the sky was not clear.

H. Observed in the 15th degree of Libra, at 2° 32′ north latitude, around apogee: on May 17, at 10^h counted from noon; counted from the conjunction likewise, in hour 10 of day 12.

I. Observed in the 27th degree of Libra, at 3° 24′ of northern latitude, around apogee; on May 18, at 11^h counted from noon, which counted from the conjunction is hour 11 of day 13.

K. Observed in the 8th degree of Scorpio, at 4° 5′ south latitude: on May 19, at 11^h counted from noon, which counted from the conjunction is hour 11 of day 14.

The opposition of the luminaries occurred in the 1st degree of Sagittarius, at 4° 51′ of northern latitude: on May 21, at 6^h 36^m in the evening.

1. It should be noticed here that the interval between Palus Mæotis and the limb is the widest of all at section A. Likewise, that part toward the north appears very spacious, as the thinner semicircular line clearly shows: for at that time the Moon was again found in Cancer, and likewise at almost its greatest southern latitude. Immediately afterwards, however, that space became more and more narrowed. At the time of the

quadrature it had decreased so much that the larger western lake was very little visible.

2. As for the boundary [confinium] of the quadrature, it is now seen advanced further toward the east, and it cuts entirely different spots than in the preceding lunation: for it was observed around the beginning of Virgo, and moreover 5 hours after the true opposition. The further, therefore, the sections of the quadratures press into the eastern part of the Moon, the more the spots in the western quadrant, that is, are compressed, and in turn are widened in the eastern. But when the section of the quadrature is seen to be the most westerly of all, as in the preceding diagram V — namely in the vernal quadrature (which up to now has at all times been seen in Cancer) — then the spots in the western quadrant are widened as much as they ever can be; the eastern spots, on the contrary, are the more constricted. The contrary happens around the autumnal quadrature, which lies in Capricorn, whose section is always the most easterly of all; and then the spots in the eastern quadrant are widened by as much more as they are compressed in the western quadrant. Hence it comes about that, although in these drawings the quadratures appear now larger, now smaller, they are nevertheless always in reality equally large, so that they represent exactly a quarter of the Moon — except for a certain very small particle, about which we have said enough above.
3. Moreover, this too is most worthy of note: that both the section of this quadrature and the boundary of the one that I drew in full in the year 1644, on March 15, passed by mere chance through exactly the same spots — with only this difference, that the right-hand interval, as also above, was not a little wider on March 15 than in this one observed on May 13. The reason is evident: namely, that the Moon was at that time standing in the first degree of Cancer and near the southern limit.
4. Section E presents a phase quite similar to the one I sketched on March 16; and no other difference appeared between these two than that in the

one added here the western space of Mæotis turned out a little narrower, on account of the libration motion of the disc.

5. But F, almost on every side, at once as regards the

boundary and at once as regards the motion of libration, appears entirely equal to the phase of the gibbous waxing Moon — the fourteenth, that is, in order. From this it is gathered that such similar phases can certainly occur not rarely.

6. From the quadrature up to the full moon, the interval of Mæotis, as also the northern one, decreased daily and became narrower, as the limb of the quadrature here clearly shows.

CAPUT XLVII.

Chapter XLVII.

LUNATIO LUNAE CRESCENTIS OBSERVATA, GEDANI, Anno Chriſti 1644. Menſe Julio

The Lunation of the Waxing Moon, observed at Danzig in the year of Christ 1644, in the month of July.

[Margin: Waxing lunation III.]

The conjunction of the luminaries of figure X occurred in the 12th degree of Cancer; the Moon's latitude was 4° 8′ south: on July 4, at 5^{h} 26^{m} in the evening.

A. Observed in the 1st degree of Virgo, at 0° 49′ south latitude, not far from the northern node; on July 7, at $9\frac{1}{2}^{h}$ counted from noon; but counted from the conjunction, in hour 17 of day 4.

B. Observed in the 13th degree of Virgo, at 0° 17′ north latitude, around the ascending node: on July 8, at $9\frac{1}{2}^{h}$ counted from noon; but counted from the conjunction, in hour 17 of day 5.

C. Observed in the 24th degree of Virgo, at 1° 26′ of northern latitude, on July 9, at $8\frac{1}{2}^{h}$ counted from noon; but counted from the conjunction, in hour 16 of day 6.

D. Observed in the 7th degree of Libra, at 2° 26′ north latitude, around apogee, on July 10, at $9\frac{1}{2}^{h}$ counted from noon; but counted from the conjunction, in hour 17 of day 7.

E. The quadrature of the Moon, observed in the 19th degree of Libra, at 3° 17′ north latitude, around apogee: on July 11, at 9^{h} counted from noon; but counted from the conjunction, in hour 16½ of day 8.

F. Observed in the 1st degree of Scorpio, at 4° north latitude, not far from apogee: on July 12, at 9^{h} counted from noon; but counted from the conjunction, in hour 16½ of day 9.

Diagram. Engraved plate: a full disc of the Moon with its spots drawn in outline, crossed from top to bottom by a series of curved lines — the boundaries

of illumination of the waxing lunation of July 1644. A row of capital letters, K to A from left to right, runs across the middle of the disc along the curved lines; the letters and the curves do not correspond one for one (more curves than letters).

- Above the disc (engraved script): "Lunatio Crescens." — *Waxing Lunation.*; below it "3."
- Row across the middle, left to right: K, I, H, G, F, E, D, C, B, A
- Lower left: "Fig. X."
- Lower right: "Aut. Sc." — engraved by the author

Diagram. Engraved plate: a full disc of the Moon with its spots drawn in outline, crossed from top to bottom by a series of curved lines — the boundaries of illumination of a waning lunation. A row of capital letters, K to A from left to right, runs across the middle of the disc along the curved lines; the letters and the curves do not correspond one for one (more curves than letters).

- Above the disc (engraved script): "Lunatio Decrescens." — *Waning Lunation.*; below it "I." [or "1."?]
- Row across the middle, left to right: K, I, H, G, F, E, D, C, B, A
- Lower left: "Fig. Y."
- Lower right: "Aut. Sc." — engraved by the author

G. Observed in the 12th degree of Scorpio, at 5° 2′ north latitude, on July 13, at 9^h counted from noon; but counted from the conjunction, in hour 16½ of day 10.

H. Observed in the 24th degree of Scorpio, at 5° 10′ latitude, namely around the northern limit: on July 14, at 9^h counted from noon; but counted from the conjunction, in hour 16½ of day 11.

I. Observed in the 7th degree of Sagittarius, at 5° 7′ north latitude, on July 15, at 9^h counted from noon; but counted from the conjunction, in hour 16½ of day 12.

K. Observed in the 19th degree of Sagittarius, at 5° 0′ north latitude, on July 16, at 9^h counted from noon; but counted from the conjunction, in hour 16½ of day 13.

On July 17 and 18 the sky was cloudy.

The opposition of the luminaries occurred in the 28th degree of Capricorn, at 3° 20′ of northern latitude: on July 19, at 5^h 26^m in the evening; and it was observed at 10^h in the evening. The interval at Palus Mæotis was very thin, as was each Lacus hyperboreus, which almost escaped the eye, as can also be seen from the periphery of the opposition in lunation X.

1. From this period it again appears openly and clearly in what way the motion of libration of the disc increases and decreases, and at what time this happens: namely, that in Capricorn the right interval is the narrowest of all, just as the left is the widest; but in Cancer the contrary is seen entirely.

2. Immediately from the conjunction (because the Moon was in Cancer) the interval in this lunation decreased daily, all the way to the opposition. From this one may gather that the Moon, on account of the motion of libration, was driven continually backwards, against the sequence of the signs; and otherwise this will certainly never be able to happen unless the conjunction is likewise found in Cancer and the opposition in Capricorn. This, however, I assert with the following exception: if indeed the Moon in future keeps the limits of libration perpetually in the signs just named, and continues its motion in the manner in which it has been observed so far in the years just past, but shall have undergone no other

inequalities. About all of these, however, we shall be able to become more certain over a longer stretch of time, through similar continued observations of lunations.

CAPUT XLVIII.

Chapter XLVIII.

LUNATIO LUNAE DECRESCENTIS OBSERVATA, GEDANI, Anno Chriſti 1644. Menſe Julio.

The Lunation of the Waning Moon, observed at Danzig in the year of Christ 1644, in the month of July.

[Margin: Waning lunation I.]

The opposition of the luminaries in figure Y occurred in the 28th degree of Capricorn, at 3° 20′ of northern latitude, on July 19, at 5^{h} 56^{m} in the evening.

A. Observed in the 13th degree of Aquarius, at 2° 6′ north latitude, around the intermediate points: on July 20, at 10^{h} counted from noon; but counted from the opposition, in hour 4 of day 2.

B. Observed in the 27th degree of Aquarius, at 0° 51′ of northern latitude, not far from the southern node: on July 21, at 11^{h} counted from noon; but counted from the opposition, in hour 5 of day 3.

C. Observed in the 12th degree of Pisces, at 0° 41′ latitude, namely around the southern node: on July 23, at 1^{h} from midnight; but counted from the opposition, in hour 7 of day 4.

D. Observed in the 28th degree of Pisces, at 1° 51′ south latitude: on July 24, at 3^{h} counted from midnight; but counted from the opposition, in hour 9 of day 5.

E. Observed in the 12th degree of Aries, at 2° 58′ south latitude, near perigee; on July 25, at 2^{h} counted from midnight; but counted from the opposition, in hour 8 of day 6.

F. Observed in the 26th degree of Aries, at 3° 57′ south latitude, around perigee: on July 26, at 2^{h} counted from midnight; but counted from the opposition, in hour 8 of day 7.

G. Observed in the 10th degree of Taurus, at 4° 35′ south latitude; on July 27, at 2^{h} counted from midnight; but counted from the opposition, in hour 8 of day 8.

H. Observed in the 25th degree of Taurus, at 5° 2′

of southern latitude, on July 28, at 3^{h} counted from midnight; but counted from the opposition, in hour 9 of day 9.

I. Observed in the 9th degree of Gemini, at 5° 9′ latitude, namely around the southern limit; on July 29, at 3^{h} counted from midnight; but counted from the opposition, in hour 9 of day 10.

K. Observed in the 23rd degree of Gemini, at 4° 58′ of southern latitude, at the intermediate points; on July 30, at 4^{h} counted from midnight; but counted from the opposition, in hour 10 of day 11.

The conjunction of the luminaries fell in the 12th degree of Leo, at 2° 22′ south latitude, descending: on August 2, at 4^{h} 24^{m} in the afternoon.

1. At this point I would like you to note that the Moon, following the sequence of the signs, turned itself round from the opposition all the way to section K, because it remained in the ascending signs. Hence the interval towards the left, between Palus Mareotis and the limb, always decreased and became narrower, so that the opposite interval, of Mæotis, had to grow gradually from day to day.
2. It is clear that in this lunation there is no straight quadrature section at all. This arises from the fact that at the time of the true quadrature I could observe no phase. For the quadrature itself occurred by day, and indeed around noon, so that it was possible to draw section F only before, and section G after, the quadrature itself; for that reason each section necessarily appeared curved. But if you imagine for yourself some straight line between F and G, you will at once discover from it how this quadrature section crossed the spots.
3. All the sections of illumination, each and every one, in any figures of the lunations whatever, have indeed been drawn with the greatest care through those very spots that appear in the Moon; and yet the daily intervals of illumination appear now wider, now more compressed. The reason is that, since the Moon is engaged in perpetual librational motion, there also arises from this a continual compression or dilatation of the spots. For since it is impossible to refer this sudden change of the spots to a single figure (as the more expert easily understand), certainly

it is necessary that an appearance of this kind, and a slight difference in the daily intervals of illumination, should sometimes be seen. What we have said, however, concerns only the daily intervals nearer the periphery; for in the rest, nearer the quadrature and the centre, it makes no difference whatever.

4. We certainly cannot wonder enough that these three limbs — of the conjunction, the quadrature and the opposition — change and vary in so wonderful a manner. For above, towards the north, now the limb of

the conjunction is the outermost of all, now that of the quadrature, now that of the opposition; and this indeed arises solely from the motion of libration of the disc and of the Moon's centre. Hence not only do the sections of the quadratures change every month, but those of all the other phases as well: so much so that very rarely (as becomes plainly evident from the periods of the lunations) is one phase entirely similar and equal in appearance to another in every respect.

CAPUT XLIX.

Chapter XLIX.

LUNATIO LUNAE CRESCENTIS OBSERVATA, GEDANI, Anno Chriſti 1644. Menſe Septembri:

The Lunation of the Waxing Moon, observed at Danzig in the year of Christ 1644, in the month of September.

[Margin: Waxing lunation IV.]

The conjunction of the luminaries in figure Z occurred in the 10th degree of Virgo, around the northern node, on September 1, at 6^{h} 10^{m} in the morning.

A. Observed in the 28th degree of Scorpio, at 5° 12′ of northern latitude, on September 7, at $8½^{h}$ counted from noon; but counted from the conjunction, in hour 14½ of day 7.

B. Observed in the 10th degree of Sagittarius, at 5° 14′ of northern latitude, namely around the northern limit; on September 8, at 8^{h} counted from noon; but counted from the conjunction, in hour 14 of day 8.

C. The Moon bisected [bifida], observed in the 23rd degree of Sagittarius, at 5° 3′ north latitude, around the intermediate points; on September 9, at 9^{h} counted from noon; but counted from the conjunction, in hour 15 of day 9.

On September 10 there was no opportunity for observing, because of the inclemency of the sky.

Diagram. Engraved plate of the waxing lunation 4, figure Z: a large lunar disc drawn in outline, with its spots, craters and seas, crossed by a set of boundary lines of illumination — a straight central line and curved lines on either side of it. Across the middle of the disc runs a row of engraved letters marking those boundaries. Small unlettered marks (two looped marks and a small square) stand on the rim at upper right and lower left. The plate occupies the upper two-thirds of the leaf; the rest of the leaf is blank.

- Title (top centre, engraved script): "Lunatio Creſcens." — *Waxing lunation*
- Number beneath the title: "4."
- Letter row across the disc, left to right: E., D., C, B, A
- Lower left, engraved script and capital: "fig. Z" — *figure Z*
- Lower right, small engraved script: "Aut. Sc." — the engraver's mark (*sculpsit*, "engraved")

Diagram. Engraved plate of the waning lunation 2, figure AA: a large lunar disc drawn in outline, with its spots, craters and seas, crossed by a set of boundary lines of illumination — a straight central line and curved lines on either side, crowded towards the right limb. Across the middle of the disc runs a row of engraved letters, one beside each boundary. The plate occupies the upper two-thirds of the leaf; the rest of the leaf is blank.

- Title (top centre, engraved script): "Lunatio Decreſcens." — *Waning lunation*
- Number beneath the title: "2."
- Letter row across the disc, left to right: H, G, F, E, D, C, B, A
- Lower left, engraved script and capitals: "fig. AA." — *figure AA*
- Lower right, small engraved script: "Aut. Sc." — the engraver's mark (*sculpsit*, "engraved")

D. The Moon's trine [Trigonus Lunæ], observed in the 17th degree of Capricorn, at 4° 1′ of northern latitude, around the middle distance; on September 11, at 8^{h} counted from noon; but counted from the conjunction, in hour 14 of day 11, at the third hour before the true aspect occurred.

E. Observed in the 1st degree of Aquarius, at 3° 7′ of northern latitude; on September 12, at 8^{h} counted from noon; but counted from the conjunction, in hour 14 of day 12.

The opposition of the luminaries fell in the 24th degree of Pisces, at 1° 30′ of north latitude, on September 16, at $0^{h}\ 15^{m}$ after noon.

Since the Moon in lunation Z remained only in the winter solstitial signs, the interval of Mæotis therefore varied little or not at all, and no less did these three limbs, namely those of the conjunction, the quadrature and the opposition. The space of the quadrature, however, was the narrowest of all, since the quadrature [quadra] fell around the beginning of Capricorn. For this reason it is extremely well worth noting, especially because the extreme eastern term of the progressions and retrogressions of the quadratures (such as it is) is seen from this section [sectione]. A quadrature of this kind you will certainly find scarcely a single time in a year, namely around the autumnal equinox — with this express condition, however, that the sky is clear and the quadrature occurs around evening.

Moreover this boundary [confinium] C is, to speak properly, the opposite term of the sections of the quadratures, if it is referred to the quadrature that occurred in Cancer around the equinox (such as we drew in the first diagram of the lunation).

CAPUT L.

Chapter L.

LUNATIO LUNAE DECRESCENTIS OBSERVATA, GEDANI, Anno Chriſti 1644. Menſe Septembri.

The Lunation of the Waning Moon, observed at Danzig in the year of Christ 1644, in the month of September.

[Margin: Waning lunation II.]

The opposition of the luminaries in diagram AA occurred in the 24th degree of Pisces, at 1° 30 of northern latitude, on September 16, at 0^h 51^m after noon.

A. Observed in 14 of Aries, at 3° 13′ of southern latitude, around the perigee. On September 17, at 11^h counted from noon; but counted from the opposition, in hour 10 of day 2.

B. Observed in the 19th degree of Aries, at 4° 17′ of southern latitude, around the perigee; on September 18, at 11^h counted from noon; but counted from the opposition, in hour 10 of day 3.

C. Observed in the 15th degree of Taurus, at 4° 52 of southern latitude, on September 20, at 1^h counted from midnight; but counted from the opposition, in hour 12 of day 4.

D. Observed in the 30th degree of Taurus, at 5° 11′ of latitude, namely around the southern limit; on September 21, at 1^h counted from midnight; but counted from the opposition, in hour 12 of day 5.

E. Observed in the 15th degree of Gemini, at 5° 11′ of southern latitude, descending; on September 22, at 2^h counted from midnight; but counted from the opposition, in hour 13 of day 6.

F. The last autumnal quadrature, observed in the 29th degree of Gemini, at 4° 48′ of southern latitude, on September 23, at 3^h from midnight; counted from the opposition, in hour 14 of day 7.

G. Observed in the 13th degree of Cancer, at 4° 13′ of southern latitude, at the middle distance; on September 24, at 3^h from midnight; counted from the opposition, in hour 14 of day 8.

H. Observed in the 27th degree of Cancer, at 3° 20′ of southern latitude; on September 25, at 5^h from midnight; but counted from the opposition, in hour 16 of day 9.

The conjunction of the luminaries took place in the 8th degree of Libra, at 2° 45′ of northern latitude, on September 30, at 10^h 29^m in the evening.

Let it be noted here: 1. That only two limbs clothe this lunation round about, namely the limb of the conjunction and that of the opposition; and these by chance constitute one and entirely the same circle. For since, in the 24th degree of Pisces and the 8th degree of Libra, and moreover in nearly similar northern latitude (for a difference of one degree of latitude makes almost no difference), the motion of libration and of the centre is exactly the same. From the opposition up to the quadrature the interval of Mareotis always increased to the left and became larger; after the quadrature, however, it gradually decreased again.

2. This section [sectio] of the last quadrature differs in no way at all from the quadrature of the first lunation, since this one, just like that one, around the beginning

of Cancer and the southern limit, was observed. From this, indeed, the last western term of the progressions of the quadratures is confirmed more and more. You will never fail to see such a boundary [confinium] whenever the Moon has a similar longitude and latitude. For the rest, since this quadrature too corresponds plainly and in every respect to that one, namely of the first lunation, it is also evident from this that the sections in the western quadrant are almost entirely equal with respect to the spots. Meanwhile, however, those two sections nearer the periphery do not appear entirely similar; and this arises from the fact that the conjunction of the first lunation, of the waxing Moon, and this opposition of the waning lunation did not occur at quite the same time and hour.

3. Concerning the first section A, let this be noted: that it was entirely possible for that very section to have reached as far as Palus Mæotis within the space of 24 hours. For the Moon was lingering around Aries, where that interval was not very wide; moreover it was around the perigee, so that it was quite swift; and hence that section could approach so far in so short a space of time. From this it follows that the sections towards the part of the more western periphery are sometimes advanced further in one day than at another time in two: further in one day, that is, when the opposition or conjunction occurs in Capricorn and in the perigee; but when the opposition or conjunction is in Cancer, around the apogee, the sections can scarcely reach Palus Mæotis in two days. The motion of libration, it is true, which at that time (the Moon being in Capricorn) proceeds in the order of the signs, retards the sections somewhat; and conversely the sections are advanced a little again when the Moon is in Cancer, because the motion of libration just mentioned is carried against the order of the signs. Since, however, this effect is scarcely perceptible, and likewise lies around the periphery, it can therefore do only a little either to accelerate or to retard the sections.

CAPUT LI.

Chapter LI.

LUNATIO LUNAE CRESCENTIS OBSERVATA, GEDANI, Anno Chriſti 1645. Menſe Februario & Martio.

The Lunation of the Waxing Moon, observed at Danzig in the year of Christ 1645, in the months of February and March.

[Margin: Waxing lunation V.]

The conjunction of the luminaries in diagram BB occurred in the 20th degree of Pisces, at 0° 49′ of southern latitude, on February 26, at 9^{h} 50^{m} in the morning.

A. Observed in the 12th degree of Aries, at 3° 38′ of southern latitude, around the apogee; on February 28, at 7^{h} counted from noon; counted from the conjunction, in hour 10 of day 3.

B. Observed in the 27th degree of Aries, at 4° 26′ of southern latitude, near the apogee; on March 1, at 7^{h} from noon; counted from the conjunction, in hour 10 of day 4.

C. Observed in the 12th degree of Taurus, at 5° 0′ of southern latitude, around the apogee; on March 2, at 7^{h} from noon; counted from the conjunction, in hour 10 of day 5.

D. Observed in the 26th degree of Taurus, at 5° 14′ of latitude, namely around the southern limit; on March 3, at 7^{h} from noon; counted from the conjunction, in hour 10 of day 6.

E. Observed in the 10th degree of Gemini, at 5° 6′ of southern latitude, descending; on March 4, at 8^{h} from noon; counted from the conjunction, in hour 11 of day 7.

Because the air was continually turbid, we were quite unable to observe the following phases.

F. Observed in the 22nd degree of Cancer, at 3° 5′ of southern latitude, around the intermediate points; on March 7, at 9^{h} in the evening; counted from the conjunction, in hour 12 of day 10.

G. Observed in the 19th degree of Leo, at 0° 55′ of southern latitude, not far from the southern node; on March 9, at 9^{h} from noon; counted from the conjunction, in hour 12 of day 12.

The opposition of the luminaries took place in the 10th degree of Virgo, at 1° 0′ of northern latitude, on March 12, at 11^{h} 46^{m} counted from noon.

Diagram. Engraved plate of the waxing lunation 5, figure BB: a large lunar disc drawn in outline, with its spots, craters and seas, crossed by a set of boundary lines of illumination — near-straight lines at the centre and curved lines on either side. Across the middle of the disc runs a row of engraved letters, one beside each boundary. Small unlettered marks (a small triangle, small squares and small looped marks) stand on the rim at upper right and lower left. The plate occupies the upper two-thirds of the leaf; the rest of the leaf is blank.

- Title (top centre, engraved script): "Lunatio Crescens." — *Waxing lunation*
- Number beneath the title: "5."
- Letter row across the disc, left to right: G, F, E, D, C, B, A
- Lower left, engraved script and capitals: "fig. B.B" — *figure BB*
- Lower right, small engraved script: "Aut. Sc." — the engraver's mark (*sculpsit*, "engraved")

Diagram. Engraved plate of the waxing lunation 6, figure CC: a large lunar disc drawn in outline, with its spots, craters and seas, crossed by a set of boundary lines of illumination — a near-straight line at the centre and curved lines on either side. Across the middle of the disc runs a row of engraved letters, one beside each boundary. The plate occupies the upper two-thirds of the leaf; the rest of the leaf is blank.

- Title (top centre, engraved script): "Lunatio Creſcens." — *Waxing lunation*
- Number beneath the title: "6."
- Letter row across the disc, left to right: F, E, D, C, B, A
- Lower left, engraved script and capitals: "Fig. CC" — *figure CC*
- Lower right, small engraved script: "Aut. Sc." — the engraver's mark (*sculpsit*, "engraved")

Note the following. 1. The limb at the conjunction and the limb at the opposition again form almost one and the same circle. For the motion of libration, which arises from the Moon's motion in longitude, is almost the same; the latitude does vary a little, and hence these limbs of the conjunction and of the opposition also differ somewhat from each other.

2. From the conjunction up to section E the interval grew day by day and became wider, since the Moon was then moving in the ascending signs; but after the quadrature it decreased in the same proportion and became narrower, as always happens in the descending signs.

CAPUT LII.

Chapter LII.

LUNATIO LUNAE CRESCENTIS OBSERVATA, GEDANI, Anno Chriſti 1645. Menſe Martio & Aprili.

The Lunation of the Waxing Moon, observed at Danzig in the year of Christ 1645, in the months of March and April.

[Margin: Waxing lunation VI.]

The conjunction of the luminaries in diagram CC occurred in the 8th degree of Aries, and at 3° 17′ of southern latitude, not far from the apogee; on March 27, at 8^{h} 42^{m} in the evening.

A. Observed in the 7th degree of Gemini, at 5° 10′ of southern latitude, around the limit and the apogee; on March 31, at 8^{h} from noon; counted from the conjunction, in hour 23 of day 4.

B. Observed in the 6th degree of Cancer, at 4° 3′ of southern latitude, descending. On April 2, at 8^{h} from noon; counted from the conjunction, in hour 23 of day 6.

C. Observed in the 20th degree of Cancer, at 3° 9′ of southern latitude; on April 3, at 9^{h} from noon, 9 hours after the true quadrature; but counted from the conjunction, with the seventh day complete.

D. Observed in the 2nd degree of Leo, at 2° 13′ of southern latitude; on April 4, at 6½^{h} from noon; counted from the conjunction, in hour 22 of day 8.

E. Observed in the 16th degree of Leo, at 1° 2′ of southern latitude, at the mean distance. On April 5, at 8½^{h} from noon, namely on the completed ninth day.

F. Observed in the 12th degree of Virgo, at 0° 8′ of northern latitude, around the northern node. On March 7, at 10^{h} from noon; but counted from the conjunction, in hour 1 of day 11.

The opposition of the luminaries took place in the 16th degree of Libra, at 3° 48′ of northern latitude, on April 10, at 6^{h} in the evening.

Points to observe. 1. Those three limbs that bound lunation CC are, both in position and in the motion of libration, almost equal to those three peripheries of the first lunation, in which the outermost circle relates to the quadrature, the intermediate one to the conjunction, and the third to the opposition. From the conjunction up to the quarter, in this lunation as well as in that first one, the interval of Palus Mæotis grew from day to day, but afterwards decreased again up to the full moon. The reason is that the conjunction, quadrature and opposition of both lunations were observed both in nearly the same signs and at almost the same time of year.

2. Between these sections, again, there is no straight line, that is, no perfect quarter; hence it came about that section C was drawn 8 hours after the true quadrature.
3. The reason why the daily interval of illumination between D and E appears wider than that between C and D is this: from C to D only 21 of time, but from D to E 26 hours, had elapsed. Therefore, unless the sections are observed each day at precisely the same hour, it will be impossible for the daily intervals to increase or decrease proportionally at all times, even with all other obstacles removed.

CAPUT LIII.

Chapter LIII.

LUNATIO LUNAE CRESCENTIS OBSERVATA, GEDANI, Anno Chriſti 1645. Menſe Aprili & Majo.

The Lunation of the Waxing Moon, observed at Danzig in the year of Christ 1645, in the months of April and May.

[Margin: Waxing lunation VII.]

The conjunction of the luminaries in figure DD occurred in the 6th degree of Taurus, at 4° 42′ of southern latitude, around the limit and the perigee, on April 26, at 2^{h} 20^{m} in the morning.

A. Observed in the 1st degree of Gemini, and at about 5° of southern latitude, not far from the perigee. On April 27, at 8^h from noon; counted from the conjunction, in hour 18 of day 2.

B. Observed in the 1st degree of Cancer, and at 4° 1′ of southern latitude. On April 29, at 9^h counted from noon; but counted from the conjunction, in hour 19 of day 4.

C. Observed in the 16th degree of Cancer, and at 3° 8′ of southern latitude. On April 30, at $9½^h$ counted from noon; but counted from the conjunction, in hour 20 of day 5.

D. Observed in the 29th degree of Cancer, and at 2° 13 of southern latitude; on May 1, at 8^h counted from noon; but counted from the conjunction, in hour 18 of day 6.

E. The quadrature, observed in the 13th degree of Leo, and at 1° 4′ of southern latitude; on May 2, at 9^h counted from noon; but counted from the conjunction, in hour 19 of day 7, namely at the time of the true quadrature.

F. Observed in the 26th degree of Leo, and at 0° 3′ of northern latitude, around the ascending node and the intermediate points. On May 3, at $9½^h$ from noon; counted from the conjunction, in hour 20 of day 8.

G. Observed in the 8th degree of Virgo, at 1° 9′ of northern latitude; on May 4, at $8½^h$ counted from noon; but counted from the conjunction, in hour 19 of day 9.

H. Observed in the 21st degree of Virgo, and at 2° 10′ of northern latitude; on May 5, at 9^h counted from noon; but counted from the conjunction, in hour 19 of day 10.

I. Observed in the 3rd degree of Libra, and at 3° 4′ of northern latitude; on May 6, at 9^h counted from noon; but counted from the conjunction, in hour 19 of day 11.

K. Observed in the 28th degree of Libra, and at 4° 23′ of northern latitude, around the apogee. On May 8, at 9^h counted from noon; but counted from the conjunction, in hour 19 of day 13.

The opposition of the luminaries fell in the 20th degree of Scorpio, and at 5° of northern latitude, around the limit and the apogee. On May 10, at 8^h in the evening.

You will observe: 1. Around phases B and C the interval between Palus Mæotis and the periphery was the widest of all; shortly afterwards it decreased day by day, up to the opposition.

2. The section of the quadrature presents almost the same appearance as the section of the quarter of the first lunation, except that the latter seems still a little more easterly. Moreover, if you consider both sections carefully, you will clearly notice that this section, namely in its upper part, somewhat further toward the west, and in the

lower part more toward the east, inclines. This comes about because the present section was observed near the northern node, but the other around

the southern limit. And from this it is clearly perceived that, with the help of these lunations, the inclinations of the cusps too, especially at the quadratures, can be explored very well — provided, that is, only that the sections are drawn diligently and accurately every month, with the work never ceasing.

CAPUT LIV.

Chapter LIV.

LUNATIO LUNAE CRESCENTIS OBSERVATA, GEDANI, Anno Chriſti 1645. Menſe Decembri.

The Lunation of the Waxing Moon, observed at Danzig in the year of Christ 1645, in the month of December.

[Margin: Waxing lunation VIII.]

The conjunction of the luminaries in diagram EE occurred in the 27th degree of Sagittarius, and at 3° 31 of northern latitude, on December 18, at 5^{h} 32^{m} in the morning.

A. Observed in the 9th degree of Aquarius, at 0° 10′ of northern latitude, around the southern node; on December 21, at 5^{h} from noon; counted from the conjunction, in hour 12 of day 4.

B. Observed in the 4th degree of Pisces, and at 2° 2′ of southern latitude; on December 23, at $5½^{h}$ counted from noon; but counted from the conjunction, in hour 13 of day 6.

C. Observed in the 17th degree of Pisces, at 2° 59′ of southern latitude, in the intermediate points; on December 24, at 5^{h} from noon; counted from the conjunction, in hour 12 of day 7.

D. The quadrature, observed in the 1st degree of Aries, at 3° 52′ of southern latitude; on December 25, at 7^{h} in the evening from noon; but counted from the conjunction, in hour 14 of day 8, 1 hour after the true quadrature.

E. Observed in the 13th degree of Aries, at 4° 35′ of southern latitude; on December 26, at 6^{h} counted from noon; but counted from the conjunction, in hour 13 of day 9.

F. Observed in the 28th degree of Aries, at 5° 2′ of southern latitude; on December 27, at 8^{h} counted from noon; counted from the conjunction, in hour 15 of day 10.

Diagram. Engraved plate of the waxing lunation 7, figure DD: a large lunar disc drawn in outline, with its spots, craters and seas, crossed by a set of boundary lines of illumination — near-straight lines at the centre and curved lines on either side. Across the middle of the disc runs a row of engraved letters, one beside each boundary. Small unlettered marks (small squares and small looped marks) stand on the rim at upper left and lower right. The plate occupies the upper three-quarters of the leaf; the rest of the leaf is blank.

- Title (top centre, engraved script): "Lunatio Creccens." — *Waxing lunation*

- Number beneath the title: "7."
- Letter row across the disc, left to right: K, I, H, G, F, E, D, C, B, A
- Lower left, engraved script and capitals: "fig. DD." — *figure DD*
- Lower right, small engraved script: "Aut. Sc." — the engraver's mark (*sculpsit*, "engraved")

Diagram. Engraved plate of the waxing lunation 8, figure EE: a large lunar disc drawn in outline, with its spots, craters and seas, crossed by a set of boundary lines of illumination — a near-straight line at the centre and curved lines on either side, the lines crowding together at the left. Across the middle of the disc runs a row of engraved letters, one beside each boundary. Small unlettered marks (small squares and small looped marks) stand on the rim at upper right and lower left. The plate occupies the upper three-quarters of the leaf; the rest of the leaf is blank.

- Title (top centre, engraved script): "Lunatio Creccens." — *Waxing lunation*
- Number beneath the title: "8."
- Letter row across the disc, left to right: K, I, H, G, F, E, D, C, B, A
- Lower left, engraved script and capitals: "fig. EE." — *figure EE*
- Lower right, small engraved script: "Autor Sculpsit" — the engraver's line, *the author engraved [it]*

G. Observed in the 13th degree of Taurus, around the southern limit; on December 28, at 10^{h} counted from noon; but counted from the conjunction, in hour 17 of day 11.

H. Observed in the 26th degree of Taurus, at 4° 58′ of southern latitude; on December 29, at 7^{h} counted from noon; but counted from the conjunction, in hour 14 of day 12.

I. Observed in the 10th degree of Gemini, at 4° 26′ of southern latitude, around the perigee; on December 30, at 7^{h} counted from noon; but counted from the conjunction, in hour 14 of day 13.

K. Observed in the 27th degree of Gemini, at 3° 31′ of southern latitude; on December 31, at 9^{h} counted from noon; counted from the conjunction, in hour 16 of day 14; 23 hours before the true quadrature.

The full moon was observed in the 11th degree of Cancer, at 2° 27′ of southern latitude, on January 1 in the year 1646, at 8^{h} in the evening — that is, at the time of the true opposition.

[Margin: Worth noting.]

Note: 1. This period of the lunation is especially remarkable, above all for this reason: its conjunction, around the very beginning of Capricorn, has no small northern latitude; the quadrature was found in the first degree of Aries; and the opposition around the beginning of Cancer, in southern latitude. Hence these three limbs, too, are seen set at almost equal distances from one another. The two outermost are as far apart as they can possibly be. The limb of the conjunction marks the limit of least libration on the right side, and on the left side the limit of greatest libration; at the same time it presents to us the

face of the summer full moon. The limb of the opposition shows almost the limit of greatest libration on the right side, and of least libration on the left; and likewise it displays to us the face of the winter full moon as it has been seen up to now.

2. The motion of libration of the disc, from the conjunction up to the opposition (since the Moon is moving in the descending signs), proceeded at all times in the order of the signs; and so the interval of the Mæotis also widened more and more from day to day.
3. At the time of the true opposition, the periphery of the full moon on its upper side, toward the north, appeared not in an even course but somewhat winding; and at once, in the first or

second hour after the full moon itself, it began to diminish — not toward the west, at the Palus Mæotis, but toward the north-west [Corum], around the Palus Amadoca. This came about chiefly for this reason: at that time, namely, the Moon had a southern latitude of 2½ degrees, from which such an appearance necessarily arises, as we showed more than sufficiently in chapter 26, on full moons.

From these observations of the lunations, then, as also from the figures of all the other phases, I consider it abundantly proved and demonstrated, among other things, not only that a certain motion of libration of the disc is found in the Moon, but also that this motion arises from no other foundation than the very motion of longitude, of latitude, and of the Moon's nodes. Hence in each month, just as the Moon runs through the whole zodiac in so great an interval, so it also partly completes that motion of libration. For there is this in addition: while the Moon stands around the beginning of Cancer, especially near the southern limit, the space between the Palus Mæotis and the western limb is always the largest of all, and the marsh just named is farthest from the limb itself; and the spot opposite it (which I have elsewhere named the Palus Mareotis) is then nearest of all to the limb. I have observed the contrary to happen, however, when the Moon is in Capricorn and at the northern limit: the Palus Mæotis is then very close to the Moon's limb, while the Lacus Mareotis is farthest from it. In the remaining signs, by reason of this varying position, these spots are seen to stand now farther from, now nearer to, the Moon's limb. This, in my judgement, would suffice on this matter. Nevertheless, so that any searcher of the stars may be made the more certain of these things, I have resolved to corroborate this motion of libration with the observations of other most distinguished men too — especially those made known to us by that man of the highest learning, Ismaël Boulliau, and by that great French luminary, Pierre Gassendi. Boulliau mentions these in his *Astronomia Philolaica*, chapter 13, pp. 179, 180, 181, book III, by means of which he tried with all his strength to investigate the period of libration and the fourth inequality. It would indeed be my intention to set every one of the fifty observations before the reader's eyes and, in place of arguments,

to use them. But, so as not to detain you too long, kind reader, I shall report here only the chief ones, which show most plainly of all when the Palus Mæotis (called the Mare Caspium by Boulliau or by Gassendi) stood farthest from the Moon's more western limb, and when it was again nearest to it; or when the Lacus Mareotis (called by them the eastern spot) was as far as possible from the eastern limb, or close to it. And yet all the other observations too, if the longitudes and latitudes of the Moon are carefully considered, agree with me as well as could be, as anyone who means to examine those observations will find in the event.

[Margin: The revolution and the limits of the Moon's libration are established by the observations of Pierre Gassendi.]

1. *The first observation was made by Pierre Gassendi in the year 1636, on September 23, at which time the eastern spot* (that is, the Lacus Mareotis) *was seen near the rising limb.* This had necessarily to happen so. For the Moon then stood in the 25th degree of Cancer, where we have always seen the interval of the Mareotis at its narrowest.

[Margin: Observation 2.]

2. *On October 8 he notes as follows: the interval of light between the Caspian spot* (that is, the Palus Mæotis) *and the western limb of the Moon was so narrowed that I have never seen it narrower.* This likewise came about because the Moon stood in Capricorn, at which time the interval of the Palus Mæotis is usually at its thinnest.

[Margin: Observation 3.]

3. *On the 20th, in the morning, he writes that the eastern spot was observed very close to the limb* — and no wonder, since the Moon was in about the 20th degree of Cancer.

[Margin: Observation 4]

4. In the two following observations, from November 9 up to the 11th, he says that *the interval between the limb and the Caspian was seen to have grown perceptibly.* This indeed favours me greatly, for the Moon was then moving in the ascending signs: on November 9 it was in Aries, and on the eleventh in Taurus, so that the interval necessarily grew.

[Margin: Observation 5]

5. *On the 19th, in the morning, the eastern spot very close to the limb. On the 20th, the same very close. On the 21st, a little farther off.* For on the 19th the Moon stood around the last degree of Leo, but on the 21st it was already in the 25th degree of Virgo.

[Margin: Observation 6]

6. *On December 5, the Caspian nearest to the edge. On the 10th, the Caspian perceptibly farther off.* For in the first instance the Moon was observed in Pisces, but in the second in about the 25th degree of Taurus; and in these signs, up to Cancer, the interval of the Caspian, or Palus Mæotis, always grows, as is well known. The remaining observations of Pierre Gassendi, also very well

agree, if you examine them carefully against the Moon's motion in longitude and in latitude — except two or three, which seem to me to waver a little, especially the one made in the year 1638 on December 20; for perhaps the Caspian was noted down in place of the eastern spot.

Now I shall turn to the observations of Boulliau. Among them certainly none is found that contradicts me even in the smallest points; rather, they all agree exactly with my observations and with my librational motion, as will be most clearly evident to anyone who examines them.

[Margin: Observations of Boulliau.]

[Margin: Observation 7]

7. For, as the same man notes, *in the year 1643, on June 2, the limb of the Caspian spot was distant from the Moon's western limb by an interval smaller than a fifth part of the width of the Spot itself. The opposite spot, situated toward the east, was distant from the eastern limb by its whole length, and even by a slightly greater interval. The opposition of the Sun and Moon had taken place that day two hours before noon.* In these words he expresses that the Caspian spot (the Palus Mæotis) was very close to the western limb, and the eastern spot (the Lacus Mareotis) very far from the eastern limb. This observation indeed agrees with me extremely well. For at that time the Moon was placed in about the 17th degree of Sagittarius, not far from Capricorn, and indeed around the northern limit; and in that configuration she always shows us just such a face, as is evident from my figures, especially from the horizontal limb of Capricorn drawn in certain full moons.

[Margin: Observation 8]

8. *On June 3, at the eleventh hour, the Moon had decreased as far as the western limb of the Caspian spot. The eastern spot appeared in the same position as on the day before. The lower Gem, which presents the appearance of a round tower, white and bright* (namely Mons Sinai), *from which a long range of mountains extends on both sides over the surface of the lunar body, stood very high on the Moon's disc.* Indeed, so it had to be, because the Moon was observed in Capricorn and at the northern limit; in that position all these appearances always present themselves to us.

[Margin: Observation 9]

9. *On September 18, at 7^h 30^m, the limb of the Caspian spot almost grazed the Moon's western limb, nor had I seen them closer before. The interval was not greater than a sixth part of the width of the Spot, which was very much narrowed in its width; indeed, it scarcely equalled a sixth part of its width.* That in this observation the appearance of the Moon was entirely similar to the two preceding ones is easily inferred from the fact that the Moon was likewise placed around Sagittarius and the northern limit.

[Margin: Observation 10.]

10. *On October 1 the eastern spot had come closer and been narrowed more* (than on September 27 and 30), *nor had I seen it so close to the limb before.* The

reason is that earlier the Moon was in Aries and Taurus, but afterwards reached Gemini and the southern limit; hence the eastern spot was seen closer to the edge, and narrower, day by day.

[Margin: Observation 11.]

11. *On October 24 the limb of the Caspian had withdrawn from the Moon's western limb by seven twelfths [ſeptem unciis] of the width; an oblong spot* (that is, the smaller western lake) *appeared between the limbs of the Caspian and of the Moon.* For since the Moon was in Aries near the southern node, that interval could appear neither larger nor smaller, nor could more than a single one of the two oblong spots be seen in it; very many phases confirm this.

[Margin: Observation 12.]

12. *On October 26, at 7^h in the evening, the limb of the Caspian stood away from the western limb by three quarters of the width of the Spot, and the Spot itself appeared at its widest; moreover, two oblong spots were seen between the edges of the Caspian and of the Moon. The eastern spot was distant from the Moon's eastern limb* (*whose roundness was not yet perfectly complete, although what was lacking would have been almost imperceptible*) *by a little more than its own width, or at least by an equal interval.* At the time of this observation, namely, the Moon had arrived at about the beginning of Taurus. Therefore not only did that interval appear more extended, but both oblong spots were now noticed between the Caspian (the Palus Mæotis) and the Moon's limb.

[Margin: Observation 13.]

13. *On November 16, in the evening, the western edge of the Caspian stood away from the Moon's western margin by a quarter of the width of the Spot.* So it is easily inferred that this spot was very close to the Moon's limb; for the Moon was moving around the last degree of Capricorn and the northern limit. In the following observations, however, made on November 16, 18, 20, 21, 22 and 30, the Caspian spot became more distant from the Moon's western limb day by day, since the Moon was then being carried through the ascending signs.

[Margin: Observation 14]

14. *On December 23, at 8^h, the Caspian was very far from the limb.* No wonder, since the Moon was observed in the 15th degree of Gemini, and moreover around the southern limit.

[Margin: Observation 15.]

15. *In the year 1644, on January 18, the Caspian was very far off.* For the Moon was revolving around the beginning of Gemini and the southern limit.

16. *On February 12 the Caspian was seen very far off.* For the Moon, at that time, was placed around Taurus, not far from the southern limit. Therefore the interval between the limbs of the Caspian and of the Moon was fairly wide; but nevertheless I am fully persuaded that it was somewhat narrower than in the preceding or the following observation.

[Margin: Observation 17]

17. *On March 13 I saw the Caspian*, he says, *very far from the limb.* For the Moon was in about the 5th degree of Gemini and at the southern limit; and at that time, as around the summer solstitial points, the spot already mentioned is always seen at its farthest from the Moon's western periphery.

From these, then, as from all the other observations of Ismaël Boulliau and Pierre Gassendi, it is more than sufficiently apparent that the greatest distance of the Caspian spot, or Palus Mæotis, from the limb, and the least distance of the eastern spot, or Lacus Mareotis, presented themselves to our view around the beginning of Cancer and the southern limit. Conversely, at the beginning of Capricorn and in the greatest northern latitude, the Palus Mæotis was always very close to the Moon's limb, and the Lacus Mareotis very far from it — as we have clearly demonstrated from all our observations of the phases, taken from the sky itself. But whether, in the manner just described, the greatest and least libration persists constantly and perpetually in Cancer and Capricorn; or whether, over a longer stretch of time, the Moon still undergoes certain inequalities; or whether the matter stands otherwise — this I certainly cannot affirm with confidence at present. This much, however, I can affirm above all: that up to now, in the time of my observations, I have found nothing other than that the limits of libration were continually observed in those signs, namely Cancer and Capricorn. I am therefore entirely of the opinion that the limbs of greatest and least libration in the Moon, with respect to the spots, will never vary; but that the motion of greatest and least libration, that is, its limits, will not remain perpetually in the same signs, but will in time, following the retrogression of the nodes, gradually move out of Cancer and Capricorn. Since, however, this could by no means be detected by us in so short a span of time — only a few years, that is (as intelligent judges of celestial matters will readily grant) — it will therefore be most

necessary that each and every tireless explorer of the celestial vault, applying indeed the greatest diligence as well as constancy, should henceforth also attend to whether such a librational motion persists in all respects in the Moon with the passage of time, or not; so that it too may be bound by continuous and indubitable observations of many years, consistent with the laws of nature. This they will doubtless achieve with no little success if they faithfully follow the path indicated above, worn by continuous periods of lunations. I would therefore also, most courteously, urge and entreat them to apply themselves to this matter as much as they possibly can, and to leave nothing untried that is not unable to serve the full investigation of this librational motion of the Moon. As for me, I shall not let sleep be so dear to me that the investigation of so great a matter is not dearer. Hence I also promise, as if by formal pledge and solemnly, that whatever I shall notice hereafter I will gladly communicate to those who cultivate mathematics.

CAPUT LV.

Chapter LV.

EX PHASIUM NUDO ASPECTU, LOCUM Lunæ circiter verum, diſtantiam luminarium, Lunæque ætatem explorare: nec non adminiculo figuræ phaſium primariæ, genuinam quantitatem, atq; proportionem diametrorum ſtellarum, novâ quâdam ratione inveſtigare.

To find, from the mere appearance of the phases, the approximately true place of the Moon, the distance of the luminaries, and the Moon's age; and also, with the aid of the primary figure of the phases, to investigate by a certain new method the genuine size and the proportion of the diameters of the stars.

No one, certainly, can deny that the mathematical arts — above all astronomy, geography and navigation — are extremely necessary for the human race to know; for no one is ever found in the whole world, of whatever condition he may be, who cannot hope for notable benefit from this or that part of mathematics. It therefore follows quite evidently that all those sciences and arts that assist, adorn and advance the mathematics just mentioned are not only most useful, but deserve to be highly valued by us. Since, therefore, Selenography lends helping hands to astronomy and geography as well as to navigation, as from the following

[Margin: Selenography is not the least of the mathematical sciences.]

will become eminently clear — I shall not, I think, be mistaken if I call it the little gem of the mathematical arts. Nor can I persuade myself otherwise than that Selenography will be dearer than any gem, especially to lovers of the stars, since it displays to them, as if before their very eyes, the almost innumerable and also very varied phases of the Moon, with their wonderful changes. In this way they are at the same time led, as if by the hand, to the most diverse meditations and contemplations (than which nothing can be more delightful), physical as well as mathematical — that is, to the investigation of exceedingly many things hidden in the theatre of nature.

[Margin: Selenography opens the doors for us to things most abstruse in nature.]

Finally, too, the mind of all of us will be stirred more and more by the sight set before it of such stupendous divine works as are seen here, so that by it the maker and creator himself, by whom all things were founded for the benefit and delight of the human race, may be all the more looked up to, praised and celebrated — a duty which it especially befits us Christians to remember, to whom it is clearly prescribed in Holy Scripture.

[Margin: With the help of Selenography we cultivate astronomy.]

But so as not to detain the reader too long here, as it were on the threshold, I shall at once proceed to show, briefly but not obscurely, how very much

Selenography contributes to cultivating — that is, to correcting and perfecting — the whole of astronomy: that queen of the sciences, I say, from which geography, and navigation in particular — indeed, what is more, the remaining parts and arts of the whole of mathematics as well — receive much light. For just as no one can or should doubt that observations of the celestial bodies have given birth to astronomy (such as we now have it), so it remains that it must at all times be enlarged by those same observations, and that its professors, if they have erred anywhere in teaching it, must be courteously called back onto the road. And indeed the case stands no differently with astronomy than with the other human sciences: all of these, astronomy with them, carry much imperfection, since we wretched mortals fall short both in talent and in length of life, so that we cannot accomplish anything complete and perfect in every part, even if we strive more boldly. And I believe God wishes to claim this for himself alone: that his works, made by himself,

and examined, ought to be good, that is, perfect; but to us he has left this: that we should all, as far as we can, be occupied in due order and at all times in contemplating, investigating and imitating them, but by far most of all in praising him.

[Margin: Astronomy has not yet been brought to the summit of perfection.]

Likewise, then, much still remains in astronomy, in its systems as well as concerning the motions of the stars, that we do not yet have sufficiently explored; so that there is certainly no lack of things to be dug out and brought to light by the tireless study of those who search the stars. Hence we must indeed devote ourselves to assiduous and continuous observations of the stars, and especially of eclipses, solar and lunar alike, as well as of the other planets and of the stars; for the more accurately these are made, the more certain will astronomical matters, and with them all things that depend on them, be rendered.

[Margin: Thanks to Selenography, observations of eclipses can in future be made far more accurately.]

I would have you know this for certain: with the help of this Selenography we shall in future undertake all such observations, each and every one, with far happier success than has been achieved hitherto; so that by their means it will be easy to investigate more exquisitely and accurately not only the motion of the Moon and its various inequalities (which have at all times given astronomers much trouble), but also the longitudes of places, on which all geography and navigation rest.

[Margin: The motion of libration very useful:]

Before we gird ourselves to disclose the method of these observations, and of making them with precision and without danger of errors, I have decided to prescribe to the lovers of the stars a method by which — through the librational motion of the Moon, found by us while intent on this selenographic labour, and reduced and brought to fixed astronomical laws — they may grasp in their minds many other most necessary things, which it has not been granted to

reach until now. Thus our forebears laid down that from the simple appearance of the Moon its longitude and latitude could in no way at all be detected and explored (even though this is to be done only in part, and not very accurately), if you used no other aid — for example ephemerides, calendars, celestial globes, or the fixed stars beside which the Moon stands.

[Margin: From the bare appearance of the Moon, to find its longitude and latitude.]

But now, that this can be done with the greatest ease and accurately enough, having at last explored the

libration and cusp motion of the Moon, and having constructed the primary figure of the phases, you will clearly see.

For just as it is more than sufficiently evident, from what has been said above here and there, how the motion of the Moon's libration can be traced for some definite time from a given longitude and latitude of the Moon, so also, conversely, given the motion of libration, the longitude and latitude of the Moon are known — not so exactly, indeed, but nonetheless in a looser way.

[Margin: How is the motion of libration to be learned?]

And at the outset, indeed, the motion just mentioned is detected in this way: from the interval that lies between the Palus Mæotis and the Palus Mareotis, and also from the northern and southern part, observed with the help of the telescope. Observe carefully, please, whether in the waxing phases of the Moon the interval at the Palus Mæotis is so wide that those two rather oblong western spots are very clearly visible. For if this interval appears so, it is evident proof that the Moon is in Cancer. But if the same interval is very much narrowed, one concludes quite rightly that the Moon is lingering about Capricorn. When, however, that space is seen to be neither very wide nor very compressed, it is a sign that the Moon is about Aries or Libra.

[Margin: To judge in which sign the Moon stands.]

Moreover, since no one is easily unaware which month we are in, it is also clear of itself in which sign the Sun is; so that nothing prevents one from conjecturing from this as well whether the Moon occupies Aries or Libra — although in each of those signs that interval of the Mæotis has the same width. From these things, then, you will know in a looser way (for I readily grant that this cannot be done exactly) when the Moon is at the cardinal points. Now, likewise, we shall teach how the Moon, standing in the remaining signs as well, cannot fail to be traced.

And first, equipped with the telescope, when you have looked at the Moon well, inscribe freehand on the primary figure of the phases — the one constructed for the sake of observations and inserted in Chapter 44 — its limb, through the same spots visible on the face of the Moon, and set out the interval according to its true image. This done, find with the primary radius of the figure the centre of the Moon corresponding to the periphery and to the width of the interval; for then

it will at the same time become known in roughly which sign the Moon stands at that time, as to its longitude and its degree of latitude — provided, however, that you have also carefully studied the southern and northern parts of the Moon.

[Margin: From the boundaries of light and shadow the latitude of the Moon is best investigated.]

Secondly, this latitude of the Moon is known far more accurately from the quadratures and the full moons. In the quadratures, indeed, it is known from the section of light and shadow, if you draw that section with the help of the primary figure and compare it with the sections of the figure of Chapter 18, inserted at page 334. Here, however, very accurate consideration and discrimination are needed — namely, of how the Moon's section inclines to the other sections represented there: whether it is parallel to those observed about the limit, or to those drawn about the northern or the southern node. From these, indeed, it is afterwards gathered with certainty whether the Moon is near the limits or the nodes; and likewise, from the greater or lesser inclination of the section of light and shadow, the difference of latitude also becomes known. But I by no means keep silent about this: to carry out observations of this kind well, a most diligent and most practised observer is required, one who has thoroughly examined both the face of the Moon and the motion of its libration; otherwise all the labour will certainly be in vain.

[Margin: In what way is the latitude of the Moon to be explored at the time of full moon?]

Now, thirdly: in full moons the Moon's latitude is learned best of all from the roughness of the periphery, namely at the time of true opposition. For when the periphery of the Moon at that time appears all round with a perfectly even course, it is a sure argument that the Moon is about the nodes, or the ecliptic. But when the more southern periphery of the Moon — that is, on the lower side — is rough and jagged, this signifies that it then has its greatest northern latitude; if, on the other hand, the northern periphery, namely the upper part, appears quite lumpy and pitted, let it be plain that the Moon is lingering about the southern limit. From the greater and lesser roughness of that periphery the approximate degree of latitude also becomes known; about this, however, we have already spoken fully enough in Chapter 26, and we would have you, reader, eagerly turn your steps there.

Since, therefore, the place of the Moon can be estimated as nearly true from a simple inspection of the phases, so likewise, in the same way, the distance of the Moon

from the Sun is known. For, as I mentioned above, when the place of the Sun is given — always known by means of the months — and the place of the Moon has been found from the motion of libration, it is also possible to gather approximately the distance of the Moon from the Sun, namely from the simple appearance of the phases.

[Margin: To find the distance of the Moon from the Sun from the phases.]

Once the longitude and latitude of the Moon are known, any future face of the phases can then be predicted for any time by reason of the motion of libration: namely, what the state of the northern or the southern part of the Moon can be in respect of its extent, and whether the space of the Mæotis or of the Mareotis will appear wide or narrow at that time. It will likewise become no less clear how the faces of the quadratures will be disposed, and above all whether their sections will incline this way or that. Indeed, what is more, it will be possible to know in advance from this very many other things of this kind; but enough has already been said about them in the foregoing.

[Margin: Whether one may conjecture the age of the Moon from the quantity of the phases?]

For the rest, the question is asked here whether we can also investigate the age of the Moon from the size and quantity of the phases. It certainly cannot be denied that the Moon, beyond all the other planets, is subject to many most diverse and wonderful motions, as is sufficiently plain from Chapter 7 of this Selenography. And from this arise those various inequalities and variations of the synodic month. For because of the varied motion just mentioned, the Moon is seen now swift, now slow, so that very rarely is one month — the synodic month, that is — entirely equal to another; and so the phases of any lunation whatever are perpetually varied, as the observations of the lunations and of the phases clearly attest. It will therefore perhaps seem to someone altogether impossible that the age of the waxing or waning Moon could be estimated exactly from the quantity of the phases; and to this is added the fact that the daily spaces of illumination appear, to the eye, quite unequal: the nearer they are to the periphery and the farther from the centre, the narrower they are seen, but the farther they are from the limb and the nearer to the centre, the wider they are judged. Moreover, because of the Moon's motion of libration, which is itself also varied in any case, those daily spaces of illumination and the sections of the phases, still more and more with respect to the spots, now

are advanced, now retarded, and are varied and distorted in a wonderful manner. Notwithstanding this, however, I shall easily disclose a clear method by which you will be able to gather, not far from the truth (for even if it will sometimes stray a little, it will nevertheless be by only one or two hours, owing, say, to the dilatation and compression of the spots), up to the quadrature, whether in the waxing or in the waning phases, what the age of the Moon is from conjunction, or how many days have elapsed since opposition. And when the quadratures are past, you will know roughly how many days and hours will remain until the full moon in a waxing lunation; in a waning one, however, how many days will still be left until the conjunction of the luminaries. Thus it will be possible to investigate fully what we have just described from the appearance of any phase whatever.

[Margin: A method of exploring the age of the phases is disclosed.]

When, therefore, you intend to examine these things, and indeed without any other prior knowledge of the Moon's longitude and latitude, then consider

that present phase carefully, applying the telescope at the same time (but it is certainly necessary that the lunar spots and the motion of its libration be thoroughly familiar to you, as I have already said quite often). Besides this, contemplate likewise with accuracy the interval visible — in the phases of the waxing Moon, that is — between the western limb and the Palus Mæotis, and no less the width of the hyperborean region; so that afterwards you can describe, on the figure of the primary delineation, the limb according to the librational motion found, and matching the phase — which will certainly be done without difficulty by a practised observer. With the limb of the phase whose age you wish to explore described in this way, draw the boundary of light and shadow with the greatest care. After that, investigate with compasses the amplitude of the phase about its middle and its greatest width, namely by the scale or measure of the phases, the one placed beside the primary delineations and divided into 100 small parts. And so, with the width also found, look up in the table below what number corresponds to it. If you find it exactly, you will at once see, from the left side of this little table, how many days old the Moon is, counted from conjunction. If, however, the width of the phase from the scale set out is not precisely in this

little table, then a proportional part will be needed; once it is obtained, you will find out by how many hours the Moon will be further advanced in age — although (as I readily grant) it is sometimes not possible to pin the phases down in this way to within one or two hours. And this is the method of investigating the age of the Moon before the first quadrature. After the half Moon, however, one proceeds similarly, indeed, in describing the limb and the boundary; but in place of the illuminated part of the Moon, seek, with the help of the scale, the width of the dark and unilluminated part. With this width, go afterwards to the little table, looking on the right-hand side for the number belonging to it, since from it the days of age are known at once on the left. The days you find, however, you will not count from conjunction; you are to know, rather, that they are the days remaining until opposition. Then, in the waning phases of the Moon up to the last quadrature, again seek the width of the dark — that is, the deficient — part of the Moon, or the complement of the phase; the days found with the help of this width will indicate plainly the age of the Moon from opposition. Again, after the last bisection of the Moon, the days remaining until conjunction are investigated from the illuminated part of the phase.

TABELLA LUNÆ ÆTATIS.

Table of the Moon's Age.

Days of the Moon's age, counted either from conjunction or to opposition; or also from ☌ to ☍. Days.	Quantity of the phases, expressed in small parts of which the radius of the Moon's disc equals 100. Parts.
1	4
2	11

Days of the Moon's age, counted either from conjunction or to opposition; or also from ☌ to ☍. Days.	Quantity of the phases, expressed in small parts of which the radius of the Moon's disc equals 100. Parts.
3	21
4	35
5	53
6	76
7	96
8	114

[Margin: Where the author drew these numbers from.]

But if you are eager to learn, kind reader, where I derived these numbers from — that is, the quantity of the phases expressed in hundredth parts — know that I extracted and compiled them from manifold observations of the phases and from the periods of the lunations.

For the rest, if this operation is undertaken by a diligent and much-practised student of Selenography, the calculation will certainly at times agree even in the very hours. And although examples may present themselves where the true target has been missed, this will nevertheless happen rather seldom; but this error will never exceed twelve hours. With this way pointed out, I think, content for the

present time we can be, considering that this has only just been marked out, by us first of all. And yet I certainly do not doubt at all that this method of knowing the Moon's age more accurately can in future be made more accurate, provided only that the observations of the lunations are diligently continued; and perhaps I myself, as soon as I have obtained just a little leisure from my other occupations, shall construct a much more certain rule for investigating the age of the Moon, and once it is constructed I shall communicate it to the world for the sake of the public good. For I am certainly not unaware in which part some correction is still needed here, and that this matter can be remedied without very great difficulty; but this will have to be reserved for another time. For now, please, use the table granted.

[Margin: A new and most certain method of measuring the diameters of the stars.]

Further, now that certain uses of Selenography have been reviewed, one more, quite singular, will have to be published here: namely, how, with the aid of the general primary figure of the phases and of that true proportion of the spots to the diameter of the Moon, the genuine quantity and proportion of the diameters — both of the planets and of all the other stars — can be explored most easily and accurately, beyond what can be said. To measure these diameters, astronomers have hitherto spared no labour; yet in my judgement they have certainly strayed far from the true target in their determination, so that I believe they estimated the diameters of the stars far greater than they really are — indeed, that they presented them greater by a third part. Lest I seem to have

said this rashly, behold the plain truth itself, shining out most clearly from the following demonstration.

[Margin: The diameters of the stars are much smaller than the ancients ever thought.]

For, to begin with, who will go on to deny me — especially if he has well understood what was said in Chapter 3 about the observation of the fixed stars, and has himself made trial of all these things — that we can measure the diameters of the stars much more accurately and correctly with the help of telescopes than with the naked sight? Considering that our sight, aided by no other means, can easily be deceived by the adventitious light of the rays, so that it always judges the stars greater than they really are. But since the tube for the most part strips the superfluous light and the spurious rays from the stars,

[Margin: The diameters of the stars are investigated more accurately with the armed eye than with the naked eye.]

it displays their bodies quite rounded and entirely stripped of their hair; and so it certainly follows, as we have said, that the telescope is suited in the very highest degree to measuring the diameters of the stars. Even so, the tube alone is not yet sufficient for this purpose; it is altogether necessary that we also use, at the same time, some other aid — namely some celestial body whose diameter is known to us far better than that of the other stars whose diameter is to be determined. For in this way we shall be able, beyond doubt, to compare the diameter of the star we are investigating with that of this body, and to establish a definite proportion between those diameters. Now in my opinion you will never give us a celestial body better suited, at any rate for making these observations, than the lunar body, with the spots discovered on it — that is, its Mountains and Valleys, its Islands and Rocks. For since very many spots, extremely diverse in size, are found on the Moon, some larger and some smaller, standing in varied proportion to the rest, there is certainly no doubt at all that at any time, on the exposed surface of the Moon, among so countless a number, one or another spot can be found that equals in diameter either this planet or that fixed star.

[Margin: Of all means, the diameters of the stars are best determined through the lunar spots.]

But if you object that the visible diameter of the Moon is not yet sufficiently known and explored, I reply that, however the size of the lunar diameter may stand, not much depends on it so far as this matter is concerned. For this cannot prevent the true proportion between the diameter of the Moon and that of some star from being found nonetheless; rather, once the Moon's diameter has afterwards been confirmed, the diameter of the other star sought will turn out entirely and perfectly correct. For even if the Moon's diameter should moreover be set a minute or two larger or smaller, this hinders our business very little, since in that case only some slight difference of a few seconds will be noticed. On that account it matters the less that we be very anxious about it

at present, the less we and the ancients agree about the diameters of the stars, even as far as the minutes.

But now the method itself of exploring the visible diameters of the stars

I shall demonstrate. First, with the help of some excellent telescope, carefully observe the diameter of some star (this, however, should be done while the Moon is in its neighbourhood) and form a proper picture of its size for yourself; then at once run over the whole Moon and its spots, to see whether one of them is present that can be compared with this star in size (and a by no means small number of such spots will certainly be found). This observation should then be repeated several times for the sake of greater certainty.

[Margin: The method itself of investigating the diameters of the stars is set out.]

In just this way, in the year of the Christian era 1646 April 22, at half past seven in the evening [horâ mediâ octavâ veſpertinâ], I investigated the proportion of the diameters of Jupiter, Venus and the Moon. At that time the diameter of Jupiter was equal to one of three mountains, Mons Moschus on the Moon, situated by the Sinus Atheniensis of Pontus Euxinus. Venus, at the same time, was larger than Jupiter in diameter by about a third, so that on careful inspection she showed roughly the size of Mons Didymus or Mons Sipylus. Having perceived this, I weighed the primary figure of the phases very carefully: namely, how many times the diameter of the spots found was contained in the lunar diameter. I found, then, that the diameter of Mons Didymus is 1/22 part of the Moon's diameter, and the diameter of Mons Moschus about 1/29 part. Accordingly, taking the visible diameter of the Moon at that time as about 30′, it necessarily follows that the diameter of Jupiter was not greater than 1′ 2″, while the diameter of Venus equalled only 1′ 22″.

[Margin: How great the diameter of Jupiter and of Venus is.]

From this you certainly see that Venus, even though she was in perigee, is much smaller than 3′, which is indeed what the ancient astronomers estimated. At mean distance, and above all in apogee, she is found still far smaller. For I well remember that in the year 1644, when Venus was a morning star around her quadrature, she did not exceed Mons Ætna, whose diameter stands to the Moon's diameter as 1 to 39. It follows, then, that with the Moon's diameter given as 30′, the diameter of Venus is only 46″. And from this it is easily gathered that if an opportunity were given of observing her diameter in apogee too, it would be found still far smaller.

[Margin: How great the diameter of Venus is at her mean distance from the Earth.]

There is certainly no doubt in my mind that by this method the diameters not only of all the planets but also of the fixed stars themselves can be investigated. Accordingly it will not be at all inappropriate first of all to explore the diameters of all the planets and of the fixed stars of the first magnitude, so that some comparison can be made among them — namely, by how much they are larger or smaller in relation to the rest: whether by a half, a third or a quarter, and so

on. This will succeed all the more happily if the new method that I was the first to show is applied — the method, that is, of stripping the adventitious light from the fixed stars, Mars, Venus and Mercury by means of smaller holes fitted to the convex lenses.

[Margin: Once the diameters of the planets are known first, the diameters of the fixed stars too are determined without any trouble.]

Whoever delights in these contemplations will be able to carry them out successfully in the way we have described. To undertake these observations in rivalry with me, and to explore the diameters of the principal stars, I invite each and every cultivator of astronomy as courteously as I can, so that in this way one may spur on another, and so that all of us together may leave no stone unturned and procure for ourselves every aid by which it may some day be possible to arrive at the true proportion of the diameters of the stars. For this is truly and certainly of very great importance both to the whole Republic of Letters and especially to our divine astronomical art. In this very business, unless I am mistaken, I should myself already have advanced a step much further, had I not hitherto been held back night and day by other selenographic observations. Yet for that reason I shall leave nothing untried hereafter, as soon as I have brought this Selenography of ours to its longed-for end, and if (as I pray) GOD, the arbiter of all our affairs, most mercifully grants health and life.

Caput LVI.

Chapter 56.

OBSERVATIONES ECLIPSIUM LUNARIUM, atque ſtellarum occultationes, correctè ut fieri quàm maximè poteſt, inſtituere; cùm verò inprimis initia, fines, phaſeſque reliquas, tum veram phaſium quantitatem, radiumq; umbrę terrenę nova methodo, viâq; planè infallibili determinare: nec non Longitudines, hactenus planè incomperto modo inveſtigare, Globumq; Lunarem artificioſè conſtruere.

To make observations of lunar eclipses, and of the occultations of stars, as correctly as can possibly be done; and to determine, by a new and wholly infallible method and way, not only the beginnings, ends and remaining phases, but above all the true quantity of the phases and the radius of the Earth's shadow; and also to investigate longitudes by a method hitherto wholly unknown, and to construct a lunar globe skilfully.

So that observations of lunar eclipses may be made with precision by every observer whatever, and so that both the beginning and the end of the individual phases and their true quantity — and above all the Earth's shadow — may be determined accurately, it is my intention at present to make public a method that serves this purpose, and no common one at that. For an infallible knowledge of

this matter is also required in the highest degree, since the whole of astronomy, geography and the art of navigation, as we have already said more than once, rest upon these things and are supported by them alone.

[Margin: The observations of eclipses could be carried out by the ancients only with less accuracy.]

For however assiduously the ancients devoted their efforts to observations of lunar eclipses, I am not at all afraid to deny that they ever showed us any truly accurate quantity of eclipses, or a proper determination of their beginning and end. Indeed, I deny that anyone at all among all the rest who has made such observations up to now without the aid of the tube has been able to record anything certain that would have contributed anything solid either to finding the longitudes of places or to correcting geographical tables — much less to examining the motion of the Moon. This will become abundantly clear from what follows.

[Margin: To the naked eye the Moon seems to be darkened sooner, and conversely to recover her light later.]

For first, from continual observations of eclipses of the Moon, we have learned beyond all doubt that their beginning, observed with the naked eye, always seems to set in sooner than if it is seen with the armed eye; and that eclipses observed without the tube appear to end later than if you inspect them with a telescope applied, so that this difference — to half a digit, and indeed some-

times to a whole digit itself — can extend.

[Margin: A certain penumbra, at the time of eclipses, precedes the true shadow.]

For I would have you know that this true, densest and darkest shadow does not thrust itself onto the Moon all at once, in a moment, but occupies her gradually from the start. Around the beginning of an eclipse there is a shadow like smoke, very diluted or thin, which little by little, in the course of time, becomes denser until at last it ends in the blackest shadow. It can therefore undoubtedly happen that someone who makes observations without the aid of the tube takes either this penumbra, or some intermediate portion of the shadow, for the true beginning of the shadow and of the eclipse. Hence it is impossible (since observers do not all, each and every one, proceed by exactly the same way in recording the beginning and the end, nor all use tubes) for the observations to agree to the very minute.

[Margin: To the naked eye an eclipse always appears smaller than it is.]

Second, an eclipse also always appears smaller to the unarmed eye than it really is with the telescope armed, as any diligent observer of the heavens will find in actual practice. Conversely, the part of the light that is free of the eclipse always presents itself to the naked eye as larger than it is. This happens, then, in the same way as is observed in the horn-shaped and sickle-shaped phases, about which, I believe, enough has already been said in the eleventh chapter above.

[Margin: Because the dilation of the pupil differs, the same eclipse is seen now larger, now smaller.]

Besides, there is also this: when any observer views an eclipse of the Moon and its phase with the naked sight of the eyes, it appears to him either somewhat larger or smaller than to another, according as nature has granted this observer a wider or narrower pupil than the other; or also by reason of the darker or brighter medium in which the observer of the eclipse happened to be placed at the time. In the former the pupil dilates, in the latter it contracts, as we have likewise said in its proper place.

[Margin: Different observers rarely determine one and the same quantity of an eclipse.]

Hence it is very rare (unless it happens by some chance) for observers to agree among themselves in determining the quantity of eclipses. For one observer, for example, estimates a partial eclipse at 7 digits, another at 7½, while a third asserts that it fully equalled 8 digits — even though all of them were under one and the same meridian. In proof of this I could bring forward a great many examples, were it not for considerations of time; meanwhile, however, one

or two I shall attach here, which Kepler mentions in the *Astronomiae pars Optica*, chapter 11, problem 6:

[Margin: This is proved by examples.]

"Mæstlinus [Michael Mästlin] estimated the greatest defect on 1572 June 25 at precisely half the diameter. But Gemma Frisius writes that at Leuven it was eclipsed by 8 digits (*Cosmocritices*, book 2). 2. On 1601 November 29 or December 9, a good part of the Moon's body (says Kepler) remained over, but how large it was could not be discerned by anyone with confidence. Ambrosius Rhodius, for some time Tycho's calculator, estimated the defect at Wittenberg at 10 digits. 3. On 1603 November 8/18 (says Kepler again) others contended that more than a quarter was in eclipse; to me it seemed that somewhat less than this was missing; and yet the shadowed part of the circumference was visible."

From these examples it is surely clearer than daylight how slippery and unstable is the determination of the quantity of eclipses that is obtained with the naked eyes.

[Margin: It matters greatly to astronomy that eclipses be recorded correctly.]

And yet it certainly matters a great deal to record the genuine quantity of eclipses, as Kepler too, in the *Astronomiae pars Optica*, in the same chapter cited above, agrees with me on this point in these words: "It is of great importance to astronomy that partial defects be recorded correctly." And he continues in the same place, near the end of the same problem, saying: "I wish astronomers would take pains to establish some more certain methods of this observation. For on this one thing depends what is commonly reckoned of the greatest importance in astronomy: the measurement of the height and of the body of the Sun. For if the Sun's greatest parallax is 3 scruples, and one errs by a third of a digit in estimating the lunar defect, 600 semidiameters of the Earth are lost; but if the Sun's greatest parallax is 2, we shall err by 1700 semidiameters of

the Earth through the omission of a single scruple in the lunar defect, as may be seen at the head of our *Parallactica*." So far Kepler.

[Margin: It is impossible to observe eclipses accurately without the spyglass.]

We therefore conclude boldly from what we have brought forward above, again as before, that the reliability of absolutely all eclipses observed by anyone whatever and carried out without the help of the telescope wavers, and that nothing certain can be drawn from them, however very accurately they may appear to have been observed.

Since this is so, it will certainly be supremely necessary to apply every diligence and to strive with all our strength to remedy this matter, so that in future all observations, especially those of eclipses, may be made without any risk whatever of error. And if this can be done by us, we shall surely find that we have attained something of the kind that will contribute very greatly above all to determining longitudes far more precisely than could be done hitherto.

Provided only that none of all the points we shall now set out about making observations correctly is in the least neglected.

[Margin: What must be attended to in observations of eclipses, so that they may be made with greater certainty.]

First, then, it is worthwhile that each and every observer who has a mind to prepare observations of lunar eclipses should provide himself with telescopes, and should undertake no observation whatever without them.

Second, that all of them should set about undertaking their observations not by different methods but by one and the same method and procedure throughout.

Third, that this always be done with the help of some principal figure, one that represents all the spots on the face of the full moon in correct proportion and is set apart specially for this work.

Fourth, that the observers should first know the face of the Moon and its spots thoroughly, both by their position and also by name; otherwise it will be difficult, not to say impossible, to complete an exact observation.

Fifth, that each and every one should investigate most accurately the true time of each phase, taken from the altitudes of the fixed stars by means of enthymetric [enthymetricis] instruments of no mean size, without entirely neglecting clocks [automatis].

On this I shall explain my mind somewhat more fully still: namely, how these observations are to be made as accurately as possible with the aid of telescopes.

[Margin: The method of making observations of eclipses accurately.]

First, then, it is necessary that you have ready to hand a copy of the principal figure of the lunations, or phases, of the same kind, shown in chapter 44; or, what is generally preferable for observations of lunar eclipses, a copy of the archetype of the full moons, displayed in the same chapter just cited.

[Margin: The difference between the two principal figures.]

Between these two drawings there is indeed no other difference than this: the latter presents the face of the Moon and its spots exactly as they show themselves to us at the time of opposition, whereas in the former, the principal drawing of the lunations, the mountains and valleys are shown just as they appear daily through the phases. It is therefore certainly better to use the figure of the full moons for the full moons at which eclipses fall, because its face is more alike. For a practised observer, however, it makes no difference which of the two he uses, since the proportion of each diagram is entirely the same.

By what means, however, you can obtain principal phases of this kind for yourself without any labour of drawing at all, we have already shown above in chapter 44.

Second, in that very figure, describe the true limb of the Moon as given by its longitude and latitude at the time of the full moon, something we have likewise already taught several times in what precedes. If, however, you prefer another way as well, you can also, as the eclipse comes on or a little before it, draw a periphery fitting the Moon from the face of the Moon itself and from the extent of its intervals, both those of Mæotis and Mareotis and those of the more southern and more northern part. Since, however, this attempt will hardly succeed for an unpractised observer, I advise and recommend that everyone keep to the former method. Next, it is likewise necessary that you have at hand several drawings of this kind bounded by the true limb, so that when one has been marked all over with the lines of the phases, the other may be there for the sake of avoiding confusion.

[Margin: To record the beginning and the end of an eclipse correctly is a very slippery matter.]

Third: equipped with a tube of no ordinary quality, attend diligently to the beginning of the eclipse. Diligently, I say. For I would not have you ignorant that, in observing and drawing both the beginning and the end, you can easily stray from the true mark. The reason is that before the true shadow comes on, a penumbra, that is, a kind of very faint shadow, always precedes it, as we have said. It is no less my wish that this too be recorded, while keeping, however, the distinction between it and the true shadow that will soon follow. Accordingly, at the first sight of the shadow you will note in your principal figure, accurately and with the greatest care, the shadow's approach and entry into the Moon: that is, into which part of the limb it works its way, both with respect to the spots and at about which degree. At the same time, at the same moment, with the help of some fellow observer, you will determine the altitude of some fixed star with a quadrant, or some other skilfully made instrument suited to this business. In the same way, it will certainly not be beside the point to have clocks [automata] at hand that show the minutes and seconds of time, so that when the sky is veiled by small clouds and the fixed stars sometimes withdraw from view, you can nevertheless know the time.

For although at that moment these do not correspond exactly to the true time, they can nevertheless be successfully corrected by certain altitudes observed

beforehand, or, once the Sun has risen, by a sundial [ſciatericum] set on the meridian line. While, therefore, you record the first appearance of the shadow and its time by both of the methods just mentioned, you must also, in the same operation, record the inclination of the beginning of the eclipse: that is, how far it lies from the vertical point, the zenith or the nadir.

[Margin: To record the inclinations is of the very greatest necessity in the phases of eclipses.]

For it is of very great importance to know these inclinations correctly. "These," says Kepler (*Astronomiae pars Optica*, chapter 10, problem 14, page 360), "if they are observed with the utmost certainty, furnish us with arguments on the greatest matters in the motion of the Moon, and serve to save labour." Likewise on page 391, chapter 10, problem 26: "It is of great importance to astronomy and geography that the inclinations of the phases be exactly observed and recorded." How these can be recorded and observed without difficulty, by a very short way that has been unknown until now, we shall show presently.

Fourth: once the beginning of the eclipse has passed, and some phase of the Moon is now visible, you must draw it again in the principal figure, in this way. With the telescope applied, observe carefully at which spots, promontories, bays and islands the arc of the Earth's shadow ends. Having noted this, transfer that arc to the figure in exactly the same way, and at the same time record the altitude of some fixed star, the time taken from the clocks, and no less its inclination. All and each of these things must necessarily be attended to with the greatest care and diligence for every phase that is to be drawn. Moreover, the more phases are drawn, the greater the usefulness to be hoped for from such an observation, and the greater the credit it will earn among the learned, especially if all the phases agree very well with one another and answer to the standard of truth. If, however, you cannot bring all the phases into one figure, take a second, a third, indeed as many as are needed. During a total eclipse, you must likewise proceed from the beginning of the recovery of the light to its end, just as from the eclipse's beginning to the onset of total obscuration; and let no phase at all escape you, but, if the time allows, draw the limit of its light and shadow at every quarter of each digit.

Admittedly, we rarely obtain them all in this order, since very often turbulent weather and small clouds flying past the Moon hinder us, so that we must generally be content with fewer.

[Margin: On the inclinations of the phases.]

As for the inclinations of the phases, mathematicians, and among others Mästlin, Tycho and Kepler, have tried to record and investigate them in different ways, as can be seen in the latter's *Astronomiae pars Optica*, chapter 10, problem 14 and those following: partly by using a quadrant of small size, partly also with a circle divided into its parts.

[Margin: How the inclinations have been investigated until now.]

Sometimes they attended to the horns of the shadow, according to whether they were seen exactly at the top, or at the bottom of the Moon, or at one side or

the other; that is, when the horns pointed either exactly upward, lying on their backs, or downward, face down, or stood upright along the vertical, or finally when the horns of the Moon formed one and the same straight line with certain fixed stars. These methods of investigating the inclinations give observers, even practised ones, no small trouble, and they are also found to be very unreliable, as the observations everywhere testify more than sufficiently. Indeed, however carefully they applied themselves to the task, they could never be certain that they had hit the mark exactly; for they hunted the inclinations with the plainly naked eye, which is certainly a very slippery thing. This is attested by that most distinguished and most attentive observer of the stars, Schickard [Wilhelm Schickard], in his description of the observation of the eclipsed Moon [Lunae laborantis] made in the year 1631, October 29, an observation he himself mentions in his reply to Gassendi's letter on Mercury seen under the Sun.

For this reason, therefore, I shall communicate to the lovers of the stars an entirely new method, with whose help the inclinations are obtained most accurately, and indeed on the spot and with no trouble, though not without the telescope, by means of the principal figure and the *Plenilunium versatile* shown in chapter 26.

[Margin: How the inclinations may be obtained by an entirely different and certain way.]

1. At the same moment as you have noted some phase and its arc, look again at the face of the Moon with a good tube applied to your eyes; observe, that is, whether any two spots not too far apart from each other are found on the same perpendicular line. (For a telescope, especially one 5 or 6 feet long, does not take in at once spots that are very far apart, which is why this is of very little help in the task.)

Of these, certainly, some will be found at any time. If, however, no notable mountains present themselves, there will not be lacking (I know well) promontories, bays, lakes, islands, or crags brighter than the rest, which one may note. For example, one must ask whether, namely, the upper Lacus hyperboreus and the Insula Besbicus fall on a perpendicular line; or else also the Insula Besbicus with the Insula Sinai; or Mons Serrorum and the Insula Besbicus; or Lacus niger major and Mons Ætna; or the lake just mentioned with the Insula Corsica; or Lacus niger minor and the Insula Besbicus; or Mons Ætna and Mons Sinai; or Lacus niger major with the Insula Besbicus; or finally Mons Ætna and the Insula Rhodus; or other places of this kind, of which there is an almost infinite number on the Moon.

Do you ask, then, by what means this can be explored so distinctly and accurately, and whether some two particular spots are set on the same straight line? Know, then, that I have learned by experience that for observers who are accustomed to carrying out celestial observations with the telescope, and who know the lunar spots well and are skilled in them, this can certainly be done with no trouble, and indeed by simple sight alone. But if these things seem impossible to anyone, near the end of this chapter, where we have resolved to

set out some further matters on the longitudes of places, we shall disclose yet another method, one that everyone can understand, though it is not common and has never been known until now. Meanwhile, so as not to digress too far from our purpose, we shall go on with our observation of the eclipse and pursue the remaining matters that deserve attention.

2. Accordingly, take care to note diligently those two spots found on the same perpendicular line, at that very phase, that is, the one drawn at that time. Moreover, for as many phases as the occasion allows you to draw, you must also explore as many pairs of spots set on a perpendicular line, attach to each phase its own pair, and also add the altitude of some fixed star and the corresponding time. For from this perpendicular line you will afterwards find, with little trouble and by means of the *Plenilunium versatile*, the true point of the Moon's limb, or its degree.

And finally, from this vertical degree of the limb you will in turn find, as you please, the inclination of the horns themselves from the vertical: both the inclination of the upper horn from the upper or the lower point of the vertical line, and that of the lower horn, that is, the distance of each from the point just mentioned.

3. The vertical degree of the Moon's limb, however, is found in this way. First, on the figure of the *Plenilunium versatile*, stretch the thread towards C, the vertical point, if, that is, those two spots found on the same perpendicular were above the centre of the lunar disc; but if they were below the centre, stretch the thread towards the point opposite C, namely the nadir, or the lower ninetieth degree. When this is done, turn the figure of the full moon round until these two spots form a line exactly parallel to the stretched thread; you can easily judge this with the naked eye or, if you prefer, ascertain it with compasses. With the figure thus set in the proper way, you will at once have the true inclination of the face of the Moon and of its spots that the Moon showed at the time of that phase, when these two spots were observed on the perpendicular line. Then note precisely the degree lying under the thread. For if the thread is stretched towards C, then that underlying degree itself, as we have just said, is the true and proper vertical degree of the Moon. If, on the other hand, those first two spots were below the centre, so that the thread had to be extended towards the point opposite C, namely the nadir, then in that case, I say, the degree lying under the thread is not the true inclination of the Moon from the vertical point, the zenith, but the degree opposite this inclination; but if you prefer to count it from the nadir point, then you have the one you are looking for. In the same way you must proceed with all the spots that present themselves under the same perpendicular at the time of the observed phases whose inclination you want.
4. Cut out of paper an arc entirely similar to the arc of the shadow, that is, to the segments of the phases marked a little earlier at certain spots on the

principal figure. It must be noted, however, that the curvature of each and every phase, that is, of the arcs of the shadow, ought to be exactly the same, provided the sections have otherwise been drawn correctly and accurately.

but if some of them disagree with the rest, as may easily happen at times, then follow in the tracks of those that are greater in number and agree completely with one another in curvature. Next, transfer the arc, cut out of the paper as accurately as possible to the sections of the shadow, onto the *Plenilunium versatile*, and direct and set it by the guide of the spots so that it first reproduces exactly the earlier position and face of the observed phase of the eclipse. Then set the vertical degree of the limb that belongs to this phase, found a little earlier, at point C, namely the zenith; but meanwhile take careful pains that the paper arc laid on this revolving figure is not moved from its place even the slightest amount. If you do this, you will not only have the inclination of the phase, that is, of the horns of the shadow counted from the vertex, clearly and plainly before your eyes, but you will also be able to determine it distinctly in degrees on the periphery of the Moon with no trouble; and no less to state at which degree of the limb each horn stood at the very time of the observed phase. All and each of these things must afterwards be written very carefully beside this phase. The same course must be taken with the other phases observed during the eclipse, and also with the beginning and the end themselves, if you are eager to investigate all their inclinations accurately and in degrees, and at the same time to refer the true position of the horns of any phase to definite degrees of the limb, and also to indicate the vertical degree that the phases held at the time of observation. Finally, in this way anyone at all who is eager to know the stars will be able, with no great labour, to place before the eyes at any time he pleases not only the phases of the eclipse themselves, by means of the *Plenilunium versatile*, but also their inclinations, and to represent them as if to the life.

5. When all these things have been found in this way, let the inclinations be arranged in order together with the observed phases, the time noted, and the altitudes (from which the true time is also derived). But here, candid reader, you will perhaps say: what is the point of this excessive curiosity over such very small matters? You seem to me to be looking for a knot in a bulrush. To this I reply now in exactly the same words that the most learned Wilhelm Schickard used in his reply to Gassendi's letter on Mercury in the Sun, page 37:

[Margin: In the business of observation we cannot be too painstaking.]

"If to anyone these things seem too scrupulous in the more minute circumstances, let him know that no diligence can be too much here, in so subtle a business, on which not only astronomy but also a large part of geography rests; and that curiosity is of most use in this, that the agreement of two phases betrays and corrects the disagreement of some third. But I never take on trust those who simply note only the beginnings

and ends, unless they also add the intermediate ones, since I know how easy it is to slip at the extremities."

6. Now, if you wish also to determine the greatest obscuration of the eclipse, and likewise the true magnitude of the phases, in digits and parts of digits as exactly as possible, these are certainly obtained with the greatest ease: you need only take off with compasses, very carefully, the magnitude of any phase from the principal figure, according to the arcs of the shadow drawn there, and test it against the scale of ecliptic digits placed below; then what is sought will at once be apparent.

[Margin: To investigate the magnitude of eclipses properly.]

7. From these arcs, moreover, drawn on the principal figure and properly observed, you will likewise find accurately, and very quickly, the semidiameter of the Earth's shadow, which the ancients, however much effort they applied, were nevertheless in no way able to attain. First, then, let all the arcs of the phases be examined carefully with the help of compasses, to see whether the curvature of all of them is exactly a section of one and the same circle. If this is found to be so, it is a sure sign that all the phases have been observed and drawn more accurately than can be said; but if some difference among the phases is detected, then choose the arc that the greater part support. Afterwards, from this segment of a circle, once its centre has been found, let the circle itself of which it is the segment be described by problem 3, proposition 25 of book III of Euclid; or, if you prefer, mechanically, namely by marking three points on that segment, as Clavius teaches at length in the same place, in the scholium to the same proposition. Once the centre of the section, that is, of its circle, has been found, the radius of the shadow at once becomes known as well. Finally, since the diameter of the Moon is also already known from the principal figure, it will be possible to determine without difficulty the very proportion of the semidiameters of the Moon and of the shadow too, in minutes, with the help of some scale and the rule of three; as the matter will soon become clearer by an example.

[Margin: To determine the semidiameter of the Earth's shadow exactly.]

But it does seem that one should not rely entirely on a single segment of a phase; and therefore one must proceed in the same way with the remaining arcs as well, so that, namely, the truth may shine out all the more certainly from the agreement of the rest.

It would therefore be desirable for me to be able to set before the eyes of the lovers of the stars some splendid and notable example, for the sake of better understanding. But (by I know not what fate) in the last few years the inclemency of the air on our horizon has denied us eclipses to be recorded in this way, so that it has been possible to observe and draw none at all as we wished, except a single one, noticed only in these last days. When an eclipse of the Moon was approaching in the year 1646, in the month of January, the clear sky seemed, as it were, no less to favour us; but, against all hope, very

dense clouds and a very black smoke, rising suddenly near my astronomical observatory at that very time, hindered the observation almost on every side, so that it was not possible to view the Moon accurately with the telescope. Hence it happened that we noticed the beginning of that obscuration perhaps one minute too late, whatever diligence we applied; moreover, we drew no more than two phases, and even these we only snatched from the sky, as it were, by stealth. The vertical degree of the phases, however, and their inclinations could by no means be recorded properly, for the reason just given. It was indeed my intention, had the sky shone clear, to mark even the smallest details of this eclipse; but the observation did not succeed as I wished. Meanwhile I by no means despair that God, who is both Best and Greatest, will grant life and health, so that with his favour many more observations of this kind may be carried out by us, more successfully, for the advancement of astronomy.

In the meantime, however, I shall set down here that very observation of the eclipse, as it was obtained, with the drawing of the two phases. At the time of the beginning, the shadow was entering the Moon near A, namely Mons Audus of Mare Eoum, a little above Palus Mareotis. The arcs B and C show the observed phases; from them it is certainly concluded that the semidiameter of the shadow was 46′ 30″, the Moon's diameter being taken as 34′, as is clearly apparent from the small table of this observation set below.

[Margin: An example of a lunar eclipse observed in the year 1646.]

Diagram. Figure FF: the full disc of the Moon with its spots drawn in outline. A thin dark lune is filled in along the left-hand limb and lettered A at its middle. Two parallel heavy arcs cross the disc left of centre from top to bottom, lettered B (left arc) and C (right arc) at mid-height. Below the disc are two scales: on the left, "Semidiameter of the Moon", divided from 10 to 100, its first interval subdivided into small ticks; on the right, "Ecliptic digits", divided from 1 to 6, each digit halved by a tick. Engraver's line: "Aut. Sc." [the author engraved it].

- A (left limb, mid-height, on the dark lune): A
- B (foot of the left arc, mid-height): B
- C (foot of the right arc, mid-height): C
- lower left: Fig. FF.
- left scale caption: Semidiameter of the Moon; numerals 10, 20, 30, 40, 50, 60, 70, 80, 90, 100
- right scale caption: Ecliptic digits; numerals 1, 2, 3, 4, 5, 6
- lower right: Aut. Sc.

Blank verso of the plate leaf; the plate shows through in mirror image.

Obſervatio Eclipſeos Lunaris, ad diem 31. Jan. An. Chr. 1646. ſt. n. mane, ante ortum Solis, GEDANI inſtituta.

Observation of the eclipse of the Moon on 1646 January 31, new style, in the morning before sunrise, made at Danzig.

Phases of the Moon in eclipse, detected with the telescope	Altitude of the Bright Star of the Lyre, in the east	Times computed from them	Degree of the Moon's limb at the vertical	Inclinations of the horns	Semidiameter of the shadow, the Moon's semidiameter being given as 17′	
No penumbra yet	30° 3′	$3^h\ 26^m\ 0^s$				
Nothing	33° 26′	$3^h\ 51^m$ 29	86° 0′			
Nothing	37° 10′	$4^h\ 18^m\ 32^s$				
Nothing	40° 30′	$4^h\ 42^m\ 0^s$				
Beginning	46° 8′	$5^h\ 21^m\ 4^s$				The beginning of the obscuration was detected at about the 118th degree of the limb, and at Mons Audus.
4 digits	47° 57′	$5^h\ 33^m\ 36^s$			46′ 30″	
4½ digits	49° 0′	$5^h\ 40^m\ 48^s$			46′ 30″	Clouds and smoke that arose nearby robbed us of the view of the remaining phases, as also of the end of the total obscuration.
	Altitude of the star in the breast of the Swan, in the east					
11 digits	39° 0′	$6^h\ 12^m\ 52^s$				
	39° 55′	$6^h\ 19^m\ 20^s$				

[Margin: Observation of an eclipse of the Moon in the year 1647, undertaken by the author.]

For the benefit of those who are captivated by these celestial spectacles, let us add another, similar example of a lunar eclipse, which we likewise very recently happened to observe to our satisfaction. Our purpose is that all and each may grasp our meaning about what was said above all the better, and also that in future, if they so wish, they may themselves the more easily undertake observations of this kind in the same way. First, then, I shall set out in order all such phases as it was possible to notice, on account of the small clouds that kept passing across, noting the altitudes at the same time and also appending certain remarks most worthy of note. Next I shall also add a diagram, namely figure F F f*, showing how all the phases were drawn, according to the spots, at the very time of the observation: so that anyone may see with their own eyes how the sections spread over the face of the Moon at this time or that, and through which spots they passed. The numbers attached to the sections in the same diagram distinguish the phases from one another in sequence, so that they can be compared all the more readily with the altitudes [recte: altitudinibus for the printed alitudinibus] and the remarks. And the small strokes marked at the upper limb indicate the vertical point of the Moon at the very time written

beside them there; so that from these vertical points the inclination, whether of the Moon or of its spots, is evident to everyone with the greatest ease.

Obſervatio Eclipſeos Lunæ, inſtituta GEDANI, Anno à nato Chriſto 1647. die 20. Jan. ſt. n. veſp.

Observation of an eclipse of the Moon, made at Danzig in the year from the birth of Christ 1647, on January 20, new style, in the evening.

Phases of the Moon observed with the telescope	Alti-tudes	Times com-puted	Time by the clock, corrected by altitude	Which spots were observed under the same perpendicular line, and which degree of the limb was at the vertical?
	Jupiter 24° 54′	$7^h\ 12^m\ 56^s$		
	Pro-cyon 24° 45′	$7^h\ 28^m\ 40^s$		
	Sirius 13° 25′	$7^h\ 56^m\ 59^s$		
	Pro-cyon 30° 47′	$8^h\ 17^m\ 43^s$		
No penumbra.	Pro-cyon 30° 58′	$8^h\ 19^m\ 19^s$		Mons Carpathes and Mons Ætna stood perpendicularly upright. Hence it is certain that the 342nd degree of the limb was at the vertical.
Nothing.	Pro-cyon 33° 5′	$8^h\ 36^m\ 39^s$		
Nothing yet.	Pro-cyon 33° 42′	$8^h\ 40^m\ 48^s$		
The faintest trace of penumbra	Jupiter 41° 9′	$9^h\ 7^m\ 28^s$		
Penumbra somewhat denser.	Jupiter 41° 46′	$9^h\ 12^m\ 12^s$		
Penumbra very noticeable.	Jupiter 42° 24′	$9^h\ 17^m\ 40^s$		Lacus hyperboreus inferior and Insula Besbicus, so that the 345th degree was at the vertical.
Beginning	Jupiter 42° 40′	$9^h\ 19^m\ 12^s$		
1. 7/8 digit.	Pro-cyon 37° 22′	$9^h\ 24^m\ 36^s$		
2. 1½ digits and a little more	Pro-cyon 37° 44′	$9^h\ 29^m\ 17^s$		
3. 2¼ digits.	Jupiter 44° 37′	$9^h\ 34^m\ 51^s$		We found Sinus Sagaricus of Pontus Euxinus, and Insula Besbicus, in the perpendicular line; from this it becomes known that the 352nd degree of the Moon culminated.

Phases of the Moon observed with the telescope	Alti-tudes	Times com-puted	Time by the clock, corrected by altitude	Which spots were observed under the same perpendicular line, and which degree of the limb was at the vertical?
4. 2½ digits.	Jupiter 44° 55′	$9^h\ 37^m\ 23^s$		
5. 3 digits.	Pro-cyon 38° 48′	$9^h\ 44^m\ 7^s$		
6. 3⅜ digits.			$9^h\ 47^m\ 23^s$	
7. 3¾ digits.	Pro-cyon 39° 19′	$9^h\ 52^m\ 11^s$		
8. Nearly 4 digits.	Pro-cyon 39° 40′	$9^h\ 58^m\ 7^s$		
	Jupiter 48° 0′	$10^h\ 6^m\ 45^s$		
9. 4¼ digits.	Jupiter 48° 9′	$10^h\ 8^m\ 11^s$		
10. 4⅜ digits.	Cor Leo-nis 32° 55′	$10^h\ 10^m\ 31^s$		Lacus hyperboreus superior and Insula Besbicus. Therefore the 3rd degree was at the vertical.
11. 4½ digits and a little more.	Jupiter 49° 4′	$10^h\ 17^m\ 0^s$		
12. 4¾ digits.	Jupiter 49° 24′	$10^h\ 20^m\ 22^s$		
13. 5 digits.	Jupiter 50° 14′	$10^h\ 29^m\ 5^s$		
14. 5 digits and a little less	Jupiter 50° 41′	$10^h\ 34^m\ 2^s$		
15. 4½ digits			$10^h\ 45^m\ 0^s$	
16. 4¼ or a little more.			$10^h\ 49^m\ 30^s$	
17. Nearly 3¾ digits.			$10^h\ 57^m\ 0^s$	
18. 3¼ or a little more.	Jupiter 52° 58′	$11^h\ 2^m\ 59^s$		Lacus Niger Major and Byzantium; that is, the 9th degree was culminating at that time.
19. Nearly 3¼ digits			$11^h\ 3^m\ 55^s$	
20. 2¾ digits.			$11^h\ 10^m\ 2^s$	
21. 2½ digits.			$11^h\ 13^m\ 40^s$	
22. 2 digits.			$11^h\ 16^m\ 0^s$	
23. 1½, a little more.			$11^h\ 19^m\ 15^s$	
24. 1⅜ digits.	Cor Leo-nis 41° 22′	$11^h\ 20^m\ 53^s$		
25. Nearly 1⅛ digits			$11^h\ 22^m\ 20^s$	
26. ⅝ digit.			$11^h\ 24^m\ 45^s$	

Phases of the Moon observed with the telescope	Alti-tudes	Times com-puted	Time by the clock, corrected by altitude	Which spots were observed under the same perpendicular line, and which degree of the limb was at the vertical?
End.	Cor Leo-nis 42° 5′	11h 27m 44s		The left side of Lacus Niger Major, and Mons Ætna. So the 16th degree of the limb was culminating.
Dense penumbra	Cor Leo-nis 42° 19′	11h 30m 3s		
Penumbra fainter			11h 33m 16s	
Penumbra very faint.			11h 35m 48s	
End of the penumbra.			11h 38m 40s	

No.	Through which spots the sections of the shadow passed	No.	Some remarks worth noting about this eclipse
			Shortly before the beginning of the eclipse we saw all 4 circumjovials very clearly — namely three to the left of Jupiter and the fourth to its right — placed roughly like this:
Init.	The beginning occurred at about the 170th degree of the limb.	Init.	The eclipse began to darken from the lower side, and indeed towards the right, namely at about 5 degrees from the nadir point. From the perpendicular line of the ninetieth degree, however, it began to be overshadowed towards the east at about 38 degrees.
1	Through Montem Acabe, Lacum Meridionalem, and its mountain.	1	
2	Through M. Ajacem, Pal. Arabiæ; and between M. Lionem and Annæ.	2	The shadow was grazing Sinus Sirbonis.
3	Through Sinum Sirbonis, I. Didymas, M. Horeb, near M. Sinai.	3	Mons Sinai was beginning to be covered.
4	Through M. Cataracten, I. Letoam, and through the southern part of M. Sinai.	4	Mons Sinai completely covered.
5	Through the lower part of Pal. Maræot., Mare mortuum, M. Dalangveros,	5	The shadow ended around the lower part of Palus Mareotis. Likewise the right cusp stood 60 degrees from the nadir point, and the other about 40 degrees towards the east.

No.	Through which spots the sections of the shadow passed	No.	Some remarks worth noting about this eclipse
6	Through Pal. Maræotidem, Inf. Carpathon, and Taurum.	6	
7	Through the upper part of P. Maræot., below Rhod., through I. Cypr., through Lib., M. Coib.	7	
8	Through Pal. Maræotid., I. Melam, above Rhodum[15] and M. Armen.	8	The right cusp was 7[?] degrees from the nadir point, and the left 45 degrees.
9	Through P. Maræotid., M. Phœnicem, M. Cragum, and M. Sogdian.	9	
10	Through the lower part of P. Maræotid., through Tum. Celen., between M. Sog. and P. Areeſ.	10	
11	Below P. Maræotid., M. Maſicytum and Paludem Areeſam.	11	
12	Below P. Maræ., above M. Athon, below M. Sip. and Didymum, near S. ext. of the Pontus.	12	The shadow had reached as far as Sinus extremus of Pontus Euxinus.
13	Through I. Lemnam, M. Sipylum, Didym., M. Moſchum and S. ex. of the Pontus.	13	When the greatest obscuration was observed, the shadow was passing over Insula Lemnos: the right cusp was then removed 90 degrees from the nadir point, and the left 48 degrees towards the east.
14	Through Mare Syrticum, M. Athon, M. Didym., M. Tanconem and Pet. Sog.	14	
15	Through M. Cataract., I. Melam, I. Lesbicam, M. Maſicytum, M. Tanc.	15	
16	Through M. Acaben, I. Cret., I. Rhod., M. Cragum, M. Cad. and Pet. Sog.	16	The right cusp was exactly in the west, that is, removed 90 degrees from the nadir point.

[15]printed «Khodum» — the initial is inked K, a damaged R or a foul K; Rhodum by sense

No.	Through which spots the sections of the shadow passed	No.	Some remarks worth noting about this eclipse
17	Through M. Pharan, M. Nitriæ, to Mare Pamp., above Pet. Sogdianam.	17	
18	Through M. Troicum, M. Tabor, below Tanconem.	18	
19	Through M. Hor, M. Libanum, below Tanconem and above Pet. Sogdian.	19	
20	Through M. Annæ, M. Sinai, L. Thoſpidem, Petram Sogdianam.	20	Mons Sinai was beginning to be lit again.
21	Through M. Seir, Taurum, below Petram Sogdianam.	21	With one cusp at the nadir point and the other exactly in the west, the shadow ended, so that the phase at that time occupied the 4th part of the periphery of the Moon.
22	Through M. Seir, M. Calchaſtam, M. Sogdianum.	22	The right cusp was noticed entirely under the normal line that intersected the perpendicular line; the left, however, was removed 5 degrees from the nadir point towards the east.
23	Through Deſertum Raphidim, M. Caucaſum and Neroſum.	23	
24	Through M. Coibacaranos, M. Paropamiſum and Montem Neroſum.	24	
25	Through M. Techiſandam, M. Dalangveros, below M. Neroſum.	25	
26	Below Dalangveros.	26	
End.	The end occurred at about the 247th degree of the limb.	End.	The end stood at about 45 degrees from the nadir point towards the right, but only about 38 degrees from the perpendicular line of the ninetieth degree.

Diagram. A small typeset figure set beneath the remark on the satellites of Jupiter: a circle (Jupiter), with three star-shaped sorts to its left — one standing apart, then two close together beside the circle — and one star-shaped sort to its right. No letters or numerals.

But to satisfy the more inquisitive reader all the more, see: I have entered the phase of each digit in a separate figure, as can be seen in the accompanying diagram F F f∗. And although those diagrams are far smaller than one might wish them to be, the principal spots, which stand out beyond the rest, have nevertheless been sketched there with the greatest care, as far as it could be done. So, in my judgment, you can not only make out quite well the section, or phase, of each digit, but also — what is more — judge very accurately the

inclination of the Moon itself, which was to be noted at each phase; above all because those two mutually intersecting lines are marked, which always form the angle of inclination. For the line a b shows the perpendicular line, the Moon being at the ninetieth degree and near the northern node; the other, c d, indicates the line that at any given time descends perpendicularly from the vertical point of the Moon through its centre. This latter line therefore changes very rapidly, whereas the former, a b, scarcely moves from its place at all within several days. Thus from the angle that those two lines form, everyone is bound to recognise at once, at first sight, the inclination, that is, the distance of the perpendicular line of the ninetieth degree from the vertical line of the Moon. I thought it right to advise you of these things, friendly reader, in advance as it were, before I set the observation itself before your eyes.

Finally, at the end of figure F F f∗, I shall also add the transit of Jupiter that we observed. I do this chiefly so that you may thereby better grasp the rapid inclination of the lunar spots, since both this passage of Jupiter and the eclipse of the Moon occurred on the same night. Whatever else we noticed in that observation of Jupiter will be set out more fully hereafter in its proper place, above all where, in keeping with the plan of our undertaking, we deal with the occultations of stars.

With this example of an eclipse thus drawn out by us, anyone, I believe, who is not wholly unversed in mathematics cannot fail to understand how, namely, observations of this kind are to be undertaken, and the phases properly drawn according to the spots

Diagram. Engraved plate, figure F F f∗: the partial eclipse of the Moon observed at Danzig on the evening of 1647 January 20. At the head, the engraved title: *Partial Eclipse of the Moon, observed at Danzig, in the year of the Christian era 1647, on the evening of 20 January.* Below it, a large map of the full Moon, its spots drawn in outline, with "Oriens" (east) on the left and "Occidens" (west) on the right. Across its lower half runs a net of curved arcs, the successive boundaries of the Earth's shadow, crossed by a second family of lines; the arcs and lines are numbered along the edge of the disc and inside it, with "Initium" (beginning) at the lower left and "finis" (end) at the lower right. At the upper right limb a column of times marks where the shadow touched the limb. Beneath the map are two rows of small discs, each showing a phase with the shadowed segment darkened and two crossing lines drawn through the disc: the waxing phases and the waning phases of the eclipse, each labelled with its time and digit. At the right of the lower row stands a further disc without a time, with three numbered pairs of stars above it. At the foot, a scale of ecliptic digits from 1 to 6, the figure number at the lower left, and the engraver's line at the lower right.

- Title (top centre): "Eclipſis Lunæ Partialis, obſervata / GEDANI, / Anno æræ Chriſtianæ 1647, Die 20 Januarii veſperi."

- Upper right limb, top to bottom: "Hor 11 27′." (11^h 27′); "Hor 11 3′." (11^h 3′); "Hor 10 10′." (10^h 10′); "Hor 9 37′." (9^h 37′); "Hor 9 17′. circa init. Eclip." (9^h 17′, about the beginning of the eclipse); "Hor 8 19′." (8^h 19′).
- Left and right of the disc: "Oriens." (East); "Occidens." (West).
- Numerals round the edge of the grid, clockwise from the upper left: 7, 8, 9, 10, 11, 12, 13, 14, 1, 15, 16, 17, 18, 19, 20, 21, 22, 1, 23, 24, 2, 25, 3, 26, 4, 5, 6, 7, 8, 9, 10, 11, 12, 25, 13, 23; at the right end of the upper boundary, 18, 19, with a stack of smaller numerals below them [?].
- Numerals inside the grid: one series 13, 14, 14, 15 … 26, running from upper centre to lower right; a second series 1, 2, 3, 4, 6, 7, 8, running from lower left toward the centre. Some further small numerals in the right half of the grid are not read.
- Lower edge of the grid: "Initium." (Beginning), left; "finis." (End), right.
- "Phaſes Eclipſeos Creſcentes." (Phases of the eclipse, waxing): "Hor 9 19′. Initium." (9^h 19′, beginning); "Hor 9 26′. 1 Dig." (9^h 26′, 1 digit); "Hor 9 30′. 2 Dig." (9^h 30′, 2 digits); "Hor 9 44′. 3 Dig." (9^h 44′, 3 digits); "Hor 10 0′. 4 Dig." (10^h 0′, 4 digits); "Hor 10. 29′. 5 Dig." (10^h 29′, 5 digits).
- "Phaſes Eclipſeos Decreſcentes." (Phases of the eclipse, waning): "Hor 10 53′. 4 Dig." (10^h 53′, 4 digits); "Hor 11 6′. 3 Dig." (11^h 6′, 3 digits); "Hor 11 16′. 2 Dig." (11^h 16′, 2 digits); "Hor 11 22′. 1 Dig." (11^h 22′, 1 digit); "Hor 11 28′. Finis." (11^h 28′, end).
- Over the unlabelled disc at the right: three pairs of stars, numbered 1 2, 3 4, and [?] 6.
- Scale: 1, 2, 3, 4, [?], 6, labelled "Digiti Ecliptici." (Ecliptic digits).
- Lower left: "Fig. F F f∗."
- Lower right: "Autor Sculpſit" (The author engraved it).

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, and how both the semidiameter of the shadow and the magnitude of the eclipses itself ought to be correctly determined.[16]

[Margin: Another method is prescribed for judging any phases whatever.]

But if this method of ours — referring all the phases, whatever they are, to a single principal figure — should seem to anyone to demand too much labour and effort, so much so that he would scarcely dare to tackle the matter this way, I shall not be unwilling to prescribe another method for him, and a much easier one, by which even those less practised in this business can distinguish any digit of an eclipse — indeed not only the digits and half-digits themselves, but also their quarters — very accurately and with no trouble at all.

First, from the centre of the model of the phases, that is, of the full Moon, draw six circles at equal distances from one another, so that the diameter of the Moon is divided into twelve equal parts, or as many digits. Then, in each space, describe again three finer concentric circles, so that in this way the quarters

[16]this sentence begins at the foot of PDF p. 642, before the plate.

of the digits are marked as well — exactly in the manner that we taught, in Chapter 5, page 106, is to be followed in observing solar eclipses. Afterwards, once the figure of the phases, that is, of the full Moon, has been prepared in this way, you will watch carefully during the eclipse for the moment when the shadow touches these circles, or rather the spots lying beneath them. For if you note this well — without, moreover, in any way neglecting the altitudes of the fixed stars — you will determine any phases as correctly as can ever be done, not only in digits but also, as we have just said, in quarters of digits, even if you have not set about drawing the sections of the shadow at all.

Meanwhile, however, it is better, I think, that you take no less pains to be able to sketch the sections of the shadow themselves as they stretch across the spots — just as you see we have certainly done in this very observation of the eclipse. For if you draw as many phases as possible in this way, then even though they do not always come to whole digits or half-digits, you will nevertheless afterwards derive from these drawn phases, with the help of some scale and of the rule of three, the true time just as well, both of the digits and of their parts. This very thing turned out excellently for us with the smaller figures and phases of the eclipses, at no great expense of labour.

In this way, therefore, observations of lunar eclipses will certainly be made with great profit.[17] Indeed, if everything is attended to properly, more usefulness than we have ever yet dared to hope for will surely flow from it — not only for astronomy but also for the whole of geography, especially with regard to longitude. This holds above all if only each and every observer carries out the observations with the help of optical tubes and of the principal figure, or of some corrected full moon reduced to an accurate proportion; and if, likewise, to avoid confusion, they do not vary the names of the spots at all, and keep one and the same method of observing. For if they do this, the undertaking will, with God's help, be happily accomplished, and the good of astronomy will be advanced in many ways.

[Margin: If we undertake observations of eclipses by the method shown, certainly no small importance will redound from this to mathematics.]

For the rest, it is truly a thing most worthy of note that from now on there is no need to cling to, and keep watch over, as it were, the beginning of the eclipse alone; rather, around any phase whatever we can always have one beginning after another to observe — indeed as many as we please. For while the shadow continually advances further into the Moon and, progressing gradually, darkens it, it certainly cannot happen otherwise than that the periphery of the shadow is at every moment touching now this spot, now another — a mountain, that is, or a valley, a bay, a promontory, a lake or an island. So around the contacts [appulſus] of any of the most notable spots, new beginnings of the eclipse are always supplied for us to note. If these are always attended to and observed — above all simultaneously by each and every astronomer, in different regions,

[17] This sentence begins at the foot of the preceding page, printed p. 467 (PDF p. 645), with "Hac igitur ratione obſervationes Eclipſium Lunarium, ma-"; it is completed here.

with the help of one and the same principal figure — truly no small weight will be added to the investigation of longitudes.

It remains, however, before we pass on to other matters, that we further advise the lover of the stars about certain particular things to be attended to most carefully in observations in general.

[Margin: What, further, must be noticed in observations of eclipses?]

First, the observer should not make these observations with too short a spyglass — that is, one whose length is only one foot — because a tube of that kind does not bring the lunar spots into view clearly and distinctly enough. Second, he should not use too long a telescope either — of eight, say, ten or more feet — for this enlarges objects far too much and very rarely excels in clarity.

For that reason, too, the arcs of the shadow are described with its help only with great difficulty, and the perpendicular positions of the spots recognised (though knowing these is of very great importance for deriving the inclinations), because a tube of that kind shows us at a single glance an unduly small portion of the Moon. The best telescope, however — one that can always be used for observations of this kind — is, believe me, one that does not exceed five or at most six feet in length, above all if it is of outstanding quality: this we have learned by experience.

Third, it is also fitting that every observer should have at hand at the time of the eclipse not only the *Plenilunium versatile*, for showing the inclinations, but also that large selenographic map which shows the names of all the spots. In this way beginners, to whom the names just mentioned are not yet well enough known, may recall them to memory at once (namely in recording the arcs of the shadow and its contacts with the various spots, and also the spots standing in the perpendicular at this or that time), and so can commit each observation to paper the more successfully. For to hold all the names of the spots entirely in memory is truly a matter of no common skill and labour. But enough of these things.

[Margin: How are occultations of stars to be observed correctly?]

Moreover, I wish now likewise to show how occultations of stars or of planets by the Moon can be undertaken and carried out very accurately, with the help both of the principal figure of the phases, sketched in Chapter 44, and of the full moons. For above all, all observations of this kind made by the ancients rest on no solid foundation whatever, so that they are very unsteady. The ancients reached their results only by some conjecture of their own, so that from their report posterity could learn nothing more than that this or that star was covered by the Moon at this or that time. They certainly could in no way determine the true line of the path behind the Moon; and much less still did they notice at which spot, or at which degree of the limb, the star made its first ingress or its egress; nor how far the stars passed from the centre toward this side or the other; nor what degree, and what inclination, there was at the

time both of the beginning of the occultation and of the emersion; and very many other things of this kind.

These things, as we have said, they were in no way able to investigate by a sure and infallible method, however hard they strained with all their strength. And although others have sometimes tried to record such things, for the most part they were deceived by their own conjecture — as could easily be shown by various examples, if time allowed.

1. To come to the matter itself, however: eclipses of stars or of planets that originate from the Moon are to be observed in this way. On the principal figure of the lunations or of the full moons (choosing, however, whichever of the two better suits the Moon at that time), first draw its limb according to the Moon's true longitude and latitude, just as we taught for lunar eclipses. When this is done, as the time of the occultation approaches, watch the Moon very carefully with the help of the telescope, to see whether the moment of contact, or of occultation, is imminent. At the same time observe accurately, when the star is still one or two digits, or even a few minutes, away from the Moon's eastern limb, at which spot nearer the limb the first touch, or ingress, of the star is to be expected — something that each and every observer will certainly detect easily. Then you will also note another spot, nearer the centre of the Moon, which forms, say, a straight line with the star to be occulted and with that first spot nearer the limb (the one at which the star seems first to arrive). Afterwards draw a straight line through these two spots with the help of some ruler; or at least imagine one for yourself from one side of the limb (in the principal figure, that is) to the other. From this it will at once appear at which part of the opposite limb the exit of the star, or its emersion, is to be watched for.
2. Likewise, at the same moment at which the Moon with its limb at once touches the star and occults it, you will find the corrected time, either by means of some accurate clock or by the altitude of some fixed star. You will also carefully note the lunar spot at which the first contact occurs, and no less which spots form the perpendicular line: for from these data, afterwards, with the help of the *Plenilunium versatile* (as we have also taught above for lunar eclipses), both the degree of the vertical limb and the degree of the first contact become known.
3. Once the star has been occulted, it is entirely proper to this business that, for the sake of greater certainty, the altitudes of certain stars should be observed several times. Then, as the time of emersion approaches, apply the telescope [Tubospicillum] with the utmost care and watch once more for the star's egress: at which part of the limb it breaks out, and at what moment of time this happens. This is certainly never determined more accurately than if you again find the altitude of some fixed star, and also the Moon's vertical degree, by means of two spots found on the perpendicular. When all this has been properly noted, draw a straight

line through the point of occultation and the point of emersion. Through it the true translunar path will at once become clear: that is, whether the Moon passed with its centre above the star or below it, and by how many minutes, reckoned by the lunar diameter, the star stood off from the Moon's centre.

[Margin: To find the translunar path.]

4. If, moreover, you would also like to know what angle the Moon's orbit made with the ecliptic at that time, proceed in this way. First, with the help of the ephemerides, find out whether the Moon at that time is near the limits, or near which node. Having established that, set up the *Plenilunium versatile* according to the Moon's observed situation, in this way. Of the three upper points marked around the periphery of that *Plenilunium versatile* and distinguished by the signs ☋ [descending node], L and ☊ [ascending node], choose the particular one that corresponds to the Moon's place, and bring it to the upper vertical point C by turning the figure round. Then, with great accuracy and with the help of a ruler, observe at which part, with respect to the spots, the perpendicular line from point C passing through the centre divides the Moon. In your principal figure, the one in which you drew the translunar path, draw another line, entirely equal in every respect to this perpendicular line as regards the spots. Again, through the point of contact of the perpendicular line and the translunar path, draw another line meeting the just-mentioned perpendicular at right angles; it will be exactly parallel to the ecliptic. Then from the intersection of these two lines, the translunar path and the parallel to the ecliptic, or from the angle that the two make,

[Margin: To determine correctly, from the observation, the angle of the Moon's orbit with the ecliptic.]

with the help of a protractor [transportorium], that is, of some semicircle divided into degrees, you will find the true magnitude of the angle of the lunar orbit and the ecliptic, which was what had to be determined. But so that these things may also become clearer, I shall gladly present to students of selenography two by no means ordinary and most noteworthy observations of the eclipse of the Palilicium, that is, of its occultations by the Moon, and also a very rare observation of Jupiter covered by the Moon (such as, unless I am mistaken, has hardly ever been properly noticed by mathematicians until now), together with the diagrams of the observations used at the time.

Obſervatio Prima Eclipſeos Palilicii, inſtituta Anno Æræ Chriſtianæ 1644. die 15. Novemb. mane GEDANI.

First observation of the eclipse of the Palilicium, made in the year of the Christian era 1644, November 15, in the morning, at Danzig.

[Margin: Eclipses of the Palilicium observed by the author with the greatest care.]

The beginning of the occultation of the Palilicium took place by the corrected clock (for there was no opportunity at that time to take altitudes) at 3^h 5^m in the morning. It was occulted by the Moon at about the 96th degree of the limb, namely the eastern limb, at Mons Alabastrinus of the Mare Eoum; at that time the 75th degree of the Moon's limb was vertical. It emerged at 4^h $5½^m$ at the 317th degree of the western limb, at Mons Alaunus, a little above Palus Mæotis; at that moment the 78th degree of the Moon's limb was vertical. At 4^h $10½^m$ [?] after the emersion the Palilicium had moved away from the limb by a distance equal to the width of Palus Mæotis, that is, about a twelfth part of the lunar diameter. At 4^h 38^m the distance of the Palilicium from the Moon's western limb equalled the lunar semidiameter; I gathered this distance accurately from the aperture of the tube. The line of the Palilicium's course, transferred to the spots, ran through Mons Alabastrinus, Insula Corsica, Lacus Trasimenus, Mons Berosus, Mons Riphæus and Mons Alaunus; so that the beginning of the eclipse, or first occultation, was observed at about the 96th degree of the limb, and its end, or the star's emersion, at about the 315th degree.

Diagram. A full-page engraved plate titled *Observations of the Eclipses of the Palilicium*. It shows the full disc of the Moon with its spots drawn in outline, a dotted vertical diameter from F at the top to G at the bottom, and a second, heavier arc crossing the disc from the upper right to the lower edge. Two solid straight lines cross the disc from left to right, each marked as the track of the Palilicium: the upper one from A (left, with a star) to B (right, with a star), dated 1644 November 15; the lower one from C (left, with a star) to D (right), dated 1645 October 8. Beside each track runs a dotted line labelled as parallel to the ecliptic: K–L above, H–I below. At the lower left is the figure number, and beneath the disc are two engraved scales: a semidiameter of the Moon divided into 100 parts, and the ecliptic digits from 1 to 6.

- F (top of the dotted vertical): F
- A (left end of the upper track): "69.°" with a star — 69°
- star in the margin to the left of A
- K (left, dotted line): K
- upper track: "Linea Palilicii itineraria. Ao 1644 die 15 Novem." — line of the Palilicium's course, in the year 1644, November 15
- upper dotted line: "Linea Eclipticæ Parallela." — line parallel to the ecliptic
- L (right, dotted line): L
- B (right end of the upper track): "315." with a star — 315
- C (left end of the lower track): "118°" with a star — 118°
- H (left, dotted line): H
- lower track: "Linea Palilicii itineraria Ao 1645. die 8 Octob." — line of the Palilicium's course, in the year 1645, October 8
- lower dotted line: "Linea Eclipticæ Parallela" — line parallel to the ecliptic
- I (right, dotted line): I
- D (right end of the lower track): "292.°" — 292°
- G (bottom of the dotted vertical): G

- figure number: "Fig G G." — Fig. GG
- scale at lower left: "Semidiameter Lunæ." — semidiameter of the Moon, numbered 10, 20, 30, 40, 50, 60, 70, 80, 90, 100
- scale at lower right: "Digiti Ecliptici." — ecliptic digits, numbered 1, 2, 3, 4, 5, 6
- engraver's line: "Aut. Sc." — engraved by the author

as can be clearly made out from line A B of the present diagram.[18]

The limb has been drawn according to the Moon's longitude and latitude; at that time the Moon was near the beginning of Gemini and at its southern limit. The line F G, passing through the centre, is the perpendicular of the ninetieth degree [Nonagesimus], the Moon being at its southern limit. The line K L, marked with dots, is parallel to the ecliptic and cuts the line F G at right angles; with A B, however, it makes a definite angle, from which the latitude of the Moon, or the angle between the orbit and the ecliptic, is derived. About the middle of the eclipse, or the true conjunction, the Palilicium stood only 6¼′ from the centre of the Moon, so that the Moon passed with its centre below the star, while the Palilicium described a northern chord subtending 141°, as the figure clearly attests.

Altera Obſervatio Eclipſeos Palilicii, pariter hîc Dantiſci peracta, Anno 1645. die 8. Octobris ſt. n. Lunâ exiſtente gibbâ; quæ itidem in appoſito repræſentatur diagrammate.

A second observation of an eclipse of the Palilicium, likewise made here at Danzig, in the year 1645 October 8, new style, with the Moon gibbous; it too is represented in the accompanying diagram.

[Margin: Second observation of an eclipse of the Palilicium.]

	Altitude	Time reckoned from midnight
When the Moon had approached the Palilicium to a distance of 15′ — that is, before the conjunction — the altitude of Jupiter was carefully taken in the eastern quarter with a quadrant made of brass (for because of the cloudy air it was not possible to take the altitude of any fixed star).	36° 25′	$1^h\ 27^m$
The beginning of the Palilicium's obscuration fell at an altitude of Jupiter of	38° 48′	$1^h\ 43^m$
During the eclipse, the altitude of Saturn taken in the western quarter	43° 50′	$2^h\ 3½^m$
When the Palilicium emerged again from the Moon's shadow, the altitude of the bright shoulder of Orion in the eastern quarter was found to be	38° 45′	$2^h\ 57^m$
Hence, from the beginning of the Palilicium's obscuration at $1^h\ 43^m$ and its end at $2^h\ 57^m$, it follows that the middle of the Palilicium's occultation took place at Danzig at		$2^h\ 20^m$

[18] this sentence begins at the foot of p. 472, before the plate; its final word, broken "de-" there, is completed by "prehenditur" here.

	Alti-tude	Time reck-oned from mid-night
and that the whole duration lasted		$1^h\ 14^m$

But after the Palilicium (or rather the

	De-grees and min-utes	Hours and min-utes
Moon the Palilicium) had passed the Moon by 15′, reckoned from the boundary of light and shadow, the bright shoulder of Orion was raised above the horizon by	40° 3′	$3^h\ 14½^m$ [?]
Although the star just mentioned was still only 9′ distant from the true western limb of the Moon (for at that very time the Moon had already decreased by 6′ at its western limb, as appears from the section of the accompanying figure), these minutes nevertheless did not yet seem to have been covered quite exactly; and so, a little later, the altitude of Procyon in the eastern quarter was taken with the quadrant	29° 38′	$3^h\ 21^m$
A second time the altitude of Procyon was	29° 57′	$3^h\ 24^m$
And this was about the time at which the Moon reached the 90th degree of the ecliptic, namely at		$3^h\ 30^m$

The Palilicium entered the dark body of the Moon at about the 118th degree of the eastern limb, near Mons Audus, through Mons Neptunus, Mons Mysius, Promontorium Chadisia and Mons Herculis; it came out, on the other hand, near the 292nd degree. This conjunction of the Palilicium and the Moon was therefore almost central: for the star passed just below the centre of the Moon, by only a single minute, and in this observation described a southern chord subtending 174°; and it fell not far short of marking out the whole diameter in its transit, as the line C D plainly shows. Concerning this last observation of the eclipse of the Palilicium, it is above all to be noted that no difference whatever was observed between the limb in this observation and in the preceding one. This, however, happened by chance: for the Moon had almost the same longitude and latitude at the one time as at the other; hence, since the centre was the same, the limb must also have been the same.

And this is as much as we had to record here on the observation of both eclipses of the Palilicium, and we have not been unwilling to share it, most gladly, with everyone.

It remains that, in this way, we should also not leave those whom it most concerns unaware of what we were recently able to observe of that remarkable and long most eagerly awaited eclipse of Jupiter, together with our very highly

esteemed friend, the most distinguished Mr Lorenz Eichstaedt, who was intent on the same thing with us.[19]

[Margin: The eclipse of Jupiter observed by the author.]

We only wish the sky had been kinder to us then, so that we could have caught, to our full satisfaction, each and every thing that was most worth noting; but things turned out somewhat otherwise than we wanted. At first, indeed, as the Moon was rising, the sky shone quite clear; but a little before the beginning of the occultation, quite unexpectedly, the face of the sky was so completely covered on every side that no view of the Moon, or of any fixed star, was allowed us at all; and so we lost almost all hope of accomplishing anything solid in this business of observing. Unexpectedly, however, around the ninth hour and a half, the clouds near the Moon partly dispersed, so that, as we kept our eyes most intently fixed on the sky, the Moon appeared again fairly clearly. But meanwhile our Jupiter [♃ or a stop?] was certainly nowhere to be seen, however diligently we searched for it with the help of the telescope — just as if it had never existed in that vast theatre of the stars. From this we could conclude nothing else than that Jupiter was entirely covered and hidden by the Moon. We therefore watched the Moon's limb with the greatest diligence and constancy, especially the western limb, where its exit was expected, so that we should not fail to observe at least Jupiter's emersion precisely, since the inclemency of the sky had denied us the beginning of its occultation. And this, happily, we achieved here at Danzig, namely at $8^{h}\ 39^{m}\ 30^{s}$.

[Margin: Jupiter emerged near Petra Sogdiana.]

So at last the long-awaited Jupiter sprang out from the shadow of the Moon, near Petra Sogdiana, which lies at the lower bay of Mare Caspium. At that very moment I also noted carefully with which of the most conspicuous spots on the face of the Moon Jupiter itself, as it emerged, stood in one and the same straight line; and I found that this was so not only with Petra Sogdiana but also with Fretum Ponticum and Mons Ætna. Accordingly, in a principal figure intended for this purpose, we drew a straight line through those spots; at once it also showed us precisely the beginning of the occultation — namely, that it actually took place at about the 100th degree of the limb,

[Margin: Across which spots did Jupiter pass?]

and near Mons Pentadactylus, which lies in Mare Eoum. Jupiter's translunar path therefore ran through the already mentioned Mons Pentadactylus, Mons Ætna, between Mons Mysius and Olympus, through the upper of the three Montes Moschi, Fretum Ponticum, Mons Caucasus, Mons Tancon and Petra Sogdiana — beside which, again, Jupiter's exit was noticed, namely at the 275th degree of the limb. It is therefore established that the line of Jupiter's path subtended 175 degrees, taking, that is, the lower or southern part, and 185 degrees on the upper or northern part.

[Margin: The conjunction of Jupiter and the Moon was almost central.]

[19] This sentence begins at the foot of the preceding page (PDF p. 654, printed p. 474), with the words "Supereſt, ut ea etiam, quæ circa illam inſignem, atque longè exoptatiſſi-".

No less clear from this, moreover, is that this conjunction of Jupiter and the Moon was almost central, since Jupiter passed only 40″ below the Moon's centre; and this can be seen very clearly from the following diagram.

I should also like you to know, reader, that this occultation of Jupiter did not occur at the very time of the full moon, but only about the second day after the opposition. As a result the Moon's disc by no means appeared full on every side, but had decreased by almost a whole digit, namely on the western side, as is plain from the section of light and shadow A A which we drew at the time. So you will easily understand, besides, that Jupiter's first emersion took place, and was seen, not at the boundary A A itself, but 2′ 15″ further toward the west — for at that time, at that place, the boundary of light stood that far from the true limb of the Moon.

[Margin: Toward which quarter were the entry and the exit of Jupiter observed?]

Finally, since the accompanying figure G G g *, that is, the face of the Moon, shows exactly the same inclination that the Moon had at the very time of the emersion, it is surely plain to anyone, if you consider the disposition of the Moon and of the sky correctly, that the beginning of the ingress took place toward the east-south-east [Vulturnum], at a distance of 57 degrees from the nadir point, and the emersion toward the north-west, at a remove of the same number of degrees, but from the zenith point. If, however, the perpendicular of the ninetieth degree is considered, the beginning took place at about the 69th degree, distant from the upper point of the perpendicular just mentioned, and the end of the occultation at about the 69th degree, removed from the lower point of the same perpendicular.

Diagram. A full-page engraved plate of the occultation of Jupiter by the Moon observed at Danzig on 1646 December 24. The centre of the plate is a large disc of the Moon drawn in outline, its spots and craters shown as ringed and dotted shapes. Three straight lines cross the disc: a vertical line, a diagonal running from upper left to lower right, and a diagonal running from lower left to upper right, which ends at each limb in a small circle holding the sign of Jupiter. A curved line near the top and western side of the disc marks the boundary of light, lettered A at two places. Above the large disc, at the upper left, a small shaded Moon disc crossed by a vertical and a slanting line, with six numbered stars and an inscription for a transit of Jupiter in 1647; at the upper right, a second small shaded Moon disc crossed by two lines, with six numbered stars and an inscription for the eclipse of 1646 December 24. Beneath the disc is a scale of ecliptic digits numbered 1 to 6, and the figure's number at lower left.

- Top left: *Tranſitus Jovis obſerv. Ao. 1647. D. 2[?] Jan.* — Transit of Jupiter observed, 1647 January 21
- Top left, over six stars: 1, 2, 3, 4, 5, 6
- Top centre (title): *Eclipſis Jovis, obſervata GEDANI, Anno 1646. Die 24 Decemb. St. n. veſp.* — Eclipse of Jupiter, observed at Danzig, 1646 December 24, new style, in the evening

- Top right: *Eclipſis Jovis, Ao. 1646. D. 24 Dec. obſervata.* — Eclipse of Jupiter observed, 1646 December 24
- Top right, beside six stars (from the top): 6, 5 or 6 [?], 3, 4, 1 2
- Top of the disc: *Septentrio.* — North
- Left of the disc: *Oriens.* — East
- Right of the disc: *Occidens.* — West
- Foot of the disc: *Auſtrum verſ.* — Toward the south
- Along the vertical line: *Linea perpendicularis Temp. Eclipſeos* — Perpendicular line at the time of the eclipse
- Along the diagonal from upper left to lower right: *Linea Perpendicularis Nonageſimi* — Perpendicular line of the ninetieth degree
- Along the diagonal from lower left to upper right: *Vi*[[*a/s*]] *Tranſlunaris.* — Translunar path
- On the boundary of light near the top, and on the western limb: A, A
- At each end of the translunar line, in a small circle: ♃ (Jupiter)
- Inside the eastern limb: a small engraved mark [?]
- Lower left: *Fig. GGg.** — Figure GGg*
- Under the disc, over a scale: *Digiti Ecliptici.* — Ecliptic digits, with the figures 1, 2, 3, 4, 5, 6
- Lower right: *Autor Sculpſ.* — Engraved by the author

Finally, since a very good opportunity once again presented itself to us at that time to examine the true proportion of Jupiter's diameter by the lunar spots, I therefore also strove with all my strength to equate Jupiter once more to some definite spot.[20] [Margin: How large was Jupiter's diameter found to be?] So, having surveyed the Moon carefully, I found that it could be compared with no other spot at all than Mons Ætna; although, when I attended to the matter more closely, Jupiter was hardly yet equal to Ætna. Meanwhile, however, its diameter was found to be a little larger than Vallis Sinai and yet, as I have already reported, smaller than the valley of Ætna. We noticed the same in the eclipse observation above, of 1647 January 20.

From these, certainly, the true size of Jupiter's diameter is found without much labour, once the proportion between the valley of Ætna and the diameter of the Moon is known; and that proportion is indeed as 1 to 34. Now, if you presuppose the diameter of the Moon at perigee to be 34′, it follows beyond dispute that Jupiter's diameter equals just one minute, 1′ — which indeed agrees very well with the observation inserted above on page 449. But if, with the excellent P. Gassendi, you set the smaller perigean diameter of the Moon at only 31′ 6″, Jupiter's diameter will certainly come to scarcely 54′ 40″. But enough of this. Let us now add the observation of the occulted Jupiter itself, and its figure, in both a larger and a smaller form.

[20] this sentence begins at the foot of the preceding text page, p. 476.

Obſervatio Jovis à Lunâ tecti, inſtituta GEDANI An. 1646. die 24. Dec. ſt. n. veſp.

Observation of Jupiter covered by the Moon, made at Danzig in 1646, on December 24, new style, in the evening.

	Altitudes (deg. min.)	Time computed (h m s)	Time corrected by the altitudes (h m s)	
			$8^h\ 39^m\ 30^s$	Beginning of the emersion. At that time Mons Serrorum and Insula Corsica were found under the same perpendicular line; hence it is clear that the 340th degree of the limb had culminated.
1			$8^h\ 50^m\ 0^s$	Jupiter was as far from the boundary of light and shadow as Mons Ætna is from Sinus Salmydessus, that is, 6½′.
2			$8^h\ 53^m\ 0^s$	Jupiter's distance from the boundary was equal to the distance of Insula Besbicus from the Riphæi Montes, that is, about 8′.
	Right shoulder of Orion, 34° 50′	$8^h\ 58^m\ 20^s$		
3			$9^h\ 6^m\ 0^s$	Jupiter's distance from the bright limb equalled the distance of Mons Ætna from the western boundary, that is, 17′.
4	Left foot of Orion, 24° 30′	$9^h\ 18^m\ 44^s$		Jupiter's distance was as great as the distance of Mons Porphyrites from the Riphæi Montes, which at that time stood right on the boundary; that is, about 22′.

	Altitudes (deg. min.)	Time computed (h m s)	Time corrected by the altitudes (h m s)	
5	Bright right shoulder, 38° 33′	$9^h\ 38^m\ 31^s$		Jupiter was as far from the boundary as the boundary between the bright and the dark part seemed to be from the eastern limb opposite it, that is, 31′.
6	Upper limb of the [?], 29° 52′	$10^h\ 4^m\ 42^s$		Jupiter was about 40′ away from the boundary.
	Upper limb of the Moon, 30° 44′	$10^h\ 10^m\ 52^s$		
	Jupiter, 31° 50′	$10^h\ 16^m\ 14^s$		
	Mars, 29° 10′	$10^h\ 17^m\ 45^s$		
	Jupiter, 32° 18′	$10^h\ 19^m\ 35^s$		
	Jupiter, 32° 42′	$10^h\ 21^m\ 39^s$		

Altitudes (deg. min.)	Time computed (h m s)	Time corrected by the altitudes (h m s)
Jupiter, 33° 0′	$10^h\ 24^m\ 31^s$	
Canis Minor, 32° 10′	$10^h\ 27^m\ 56^s$	
Canis Minor, 32° 47′	$10^h\ 33^m\ 42^s$	
Canis Minor, 33° 7′	$10^h\ 36^m\ 50^s$	

For the rest, should anyone also wish to know what the actual beginning of Jupiter's occultation was — although, for the reason given above, I myself was not able to observe it with my own eyes — I shall nevertheless readily disclose this secret to everyone.

But how, you will ask, since it seems almost impossible? Not at all, certainly. For that this can be done successfully is owed to the observation of the most learned Master Albert Linemann, no ordinary friend of ours, made successfully at Königsberg in our Prussia. By what better fortune I do not know, it fell to him, rather than to us, to observe that beginning of Jupiter's occultation. [Margin: Beginning of the occultation of Jupiter observed at Königsberg.] As I learned from his kind letter, it took place there when the left and preceding shoulder of Orion stood at an altitude of 29° 31′, that is, at $7^h\ 53^m\ 3^s$. If from this time you subtract the difference of meridians between Danzig and Königsberg, $7^m\ 30^s$ — established many times by very many most trustworthy observations — there will remain the true beginning of the ingress here, that is, at Danzig: $7^h\ 45^m\ 33^s$; while the egress was observed by us at $8^h\ 39^m\ 30^s$. From this it follows, then, that the duration of Jupiter's obscuration extended to nearly 54^m of time — something we considered it quite wrong to pass over here and suppress in silence.

It remains, however, for us to turn to the transit of Jupiter observed in 1647 on January 21 (that is, on the very night on which the lunar eclipse described above was coming on). [Margin: Transit of Jupiter observed at Danzig.] For it deserves to be recorded no less, so that beginners in celestial observation may at the same time see by what method I observed this transit, and so that all of us may at the same time be the more confident about the perfection of our tables. The figure of this transit is set before everyone's eyes both in figure F F f* and in the preceding G G g*.

Tranſitus Jovis, obſervatus GEDANI, Anno Chriſti 1647. die 21. Januar. mane ſt. n.

Transit of Jupiter, observed at Danzig, in the year of Christ 1647, on January 21, in the morning, new style.

	Alti-tude of Arc-turus (deg. min.)	Time com-puted (h m s)	
1	36° 53′	$2^h\ 6^m\ 49^s$	The distance of Jupiter from the limb of the Moon was found to be about 40′.
2	33° 29′	$2^h\ 18^m\ 21^s$	The distance of Jupiter from the limb of the Moon equalled the diameter of the Moon, that is, 34′.
	39° 48′	$2^h\ 38^m\ 0^s$	We noticed Mons Carpathes and Byzantium under the same perpendicular line; hence it is clear that the 35th degree of the limb had culminated.
		$2^h\ 33^m\ 45^s$	Mars observed on the same perpendicular as the centre of the Moon.
3	44° 48′	$3^h\ 6^m\ 15^s$	Jupiter was no farther removed from the limb of the Moon than Mons Ætna is from the lower limb of the Moon, that is, about 21′. And Jupiter formed an entirely straight line with Mons Porphyrites and Ætna. This is something most worth observing in such transits of stars: for if it is properly attended to, you will never fail to be certain from which side of the limb the distance is to be counted; whereas if you neglect it, you will labour in vain.
4	46° 16′	$3^h\ 18^m\ 7^s$	Jupiter stood off from the limb of the Moon by exactly as great an interval as Insula Besbicus from Mons Porphyrites, that is, 15′. And Jupiter was found in a straight line with Insula Corsica and Insula Besbicus.
5		$3^h\ 45^m\ 0^s$	The distance of Jupiter was noticed to be a little greater than the interval between Mare Mediterraneum and the eastern limb of the Moon, around Insula Cercinna. At the same time Jupiter was moving in a straight line with Lacus Niger Major, and likewise with Insula Besbicus.
6		$3^h\ 57^m\ 0^s$	When the Moon was last observed, it was at most 7′ distant from Jupiter. After that we were not permitted to observe the Moon any further at all, since the sky was overcast on every side with the thickest clouds.

From these observations, certainly, as well as from what we have said here and there, it can be gathered amply, and not obscurely (especially by those who weigh the matter more deeply), that by this method observations of this kind can be carried out far more accurately indeed than they once were. So much so that I have no doubt at all that, if they are undertaken by each and every observer of the heavens with equal method and attention, they will turn to the great benefit of the republic of letters. Indeed, a most welcome opportunity is given not only of examining and correcting the motion of the Moon as accurately as possible, but also, as we have already pointed out above, of investigating the longitudes of places from the beginning and end of the occultations of stars.

I admit, indeed, that those skilled in astronomy, and other most excellent men, have at all times bent all the sinews and strength of their minds to this one end: to explore the longitudes of places in various ways. [Margin: Mathematicians have laboured greatly to investigate longitudes by different routes.] But however

many methods have been found up to now, none, in my judgement, is truly to be preferred to the one which, by means of eclipses and occultations of stars

(on the express condition that they are undertaken by everyone with great precision, above all by the method already described), is accomplished. [Margin: As far as has been found so far, longitudes are best of all traced through eclipses and occultations of stars.] Meanwhile, this one thing alone would be to be wished: that observations of this kind were undertaken and compared more often than has indeed happened so far! For this reason it will indeed be extremely necessary for us to strive with all our strength so that, in addition, yet another method of hunting out and determining longitudes may be discovered — one by which this could be done daily, anywhere at all, whenever one pleased. And there is certainly no doubt that in the course of time this method will be refined more and more by industrious and diligent minds, and brought to its perfection.

Indeed, nothing can be more certain than that the Moon, before all the other stars, is best suited to this business on account of her very swift motion — so much so that she would be a still more infallible means than the solar spots or the Jovials, if only we went forward by the road that leads straight there. [Margin: The Moon is most useful for investigating longitudes.] To reach that road, I shall moreover set before all those skilled in mathematics various methods of exploring longitudes, devised by me very recently with the help of this *Selenographia*. Not, indeed, as if I had settled in my mind the opinion that the methods I am about to name are precisely the very ones by which alone this ought to be, and can be, explored with the utmost certainty — not at all. Rather, because they are perhaps, as I am thoroughly persuaded, of such a kind that they are at the least to be held of no less account, if they are not to be preferred, than the others devised so far and known to the learned world up to now (except, however, for those methods that are carried out through eclipses and occultations of stars); and indeed so constituted that, in the course of time and through the deeper investigation of astronomers, they are not incapable of being made more certain and more perfect. And so that all the most excellent practitioners may do this, I would wish each and every one of them to be urged and asked, again and again, for the common good of mathematics, to labour toward it as best they can. I rely on the surest hope that much greater and more certain things than those I am about to make public can yet be discovered by someone else: for I would never set myself above even the least true devotee of mathematics and skilful investigator of the stars.

In our opinion, however, the first method of finding longitudes

can be set up not so absurdly by investigating the Moon's inclination, or the vertical degree of her limb. [Margin: A new method of searching out longitudes is disclosed.] For from her first rising until her setting the Moon continually varies her inclination, or vertical degree, and no less the angle between the vertical circle and her orbit; and indeed fairly quickly, within no very long time. It will therefore certainly be possible — namely, once the

vertical degree has been found exactly and the altitude of some fixed star has been explored (especially if this is attended to by different observers) — for the longitude of places to be investigated successfully in this way.

But perhaps you will ask how this vertical degree of the Moon, which shifts with her inclination, is explored at any time whatever. [Margin: How is the vertical degree of the Moon to be investigated?] You should know that this can be done excellently once the perpendicular line of two notable spots — whether they are mountains, islands, promontories, bays, lakes or marshes makes no difference — is known with the help of the telescope; that is, if one attends carefully to the moment when two particular spots, examined against a plumb-line, stand exactly upright. Once this has been explored, and with the help, indeed, of the *Plenilunium versatile*, as we indicated a little earlier in connection with the observations of lunar eclipses, that vertical degree of the limb becomes known without much trouble.

But suppose you object that it is a very slippery business to explore what is sought with the bare sight of the eyes, with no other aid applied, in such a way that the experienced could be entirely certain about this matter on every side. Then I admit that an unpractised observer, entering on this road here, easily stumbles; just as, on the other hand, I must fully grant that some veteran observer likewise cannot at all stray from the true road. Nevertheless, lest it not be open to anyone at all (who has at least some knowledge of the face of the Moon) to measure by an infallible method the perpendicular position of this or that spot, I shall disclose to the candid reader a method recently found by me, which can also be employed very conveniently for the inclinations of the phases that are to be noticed at the time of an eclipse.

To begin with, I would have you know that I apply a kind of plumb-line to the concave glass of the spyglass, by means of which the perpendicular position of two spots is discerned. [Margin: Another infallible method of tracing the perpendicular position of the spots, or the vertical degree of the Moon, at any time.] A single thread, indeed, is by no means sufficient;

since, with the eye applied, it can by no means be distinguished well enough[21]; and much less can one examine with its help the perpendicular line of two spots. Rather, something else must be at hand, namely a special instrument, fitted to the concave glass of the tube, as the one nearer the eye, and fitted in such a way that it can continually show us the perpendicular line, without any delay or risk of straying, at whatever elevation or direction the telescope may have. And although at first sight this may seem very difficult to make, it is nevertheless easily procured, just as it will be no trouble to make plain to the eager reader, in what follows, the way of constructing it.

1. Have a ring a made of bronze or of brass, of about the width and height you see in the figure below, so that it can be conveniently fitted to the

[21]this clause begins at the foot of the preceding page (PDF p. 663), "cùm id oculo admoto ſatis dignoſci nullatenus"; its verb "poſſit;", printed there as the catchword, opens this page

tube — at the place, that is, where the concave lens sits — and secured by those three thumb-screws c.

Diagram. An engraved figure across the full measure of the page showing the parts of Hevelius's plumb-line attachment for the telescope. At left, a plain ring with three knobbed screws and two side sockets; below it, a loose flat bar lying diagonally, and between the two rings an upright flat bar with a hole near its top. At right, the assembled instrument: the same kind of ring carrying two uprights, between which a disc with a wedge-shaped cut-out is hung. In the lower row: a plumb-bob on a thread ending in a hook; a half-disc carrying three small hook-shaped pieces; a ring set inside an outer rim with pivots on either side, its inner ring cut out in a wedge; and a separate disc with a wedge-shaped cut-out.

- a (left ring, inside top and front): the ring
- c (left ring, two upper knobs and one bottom knob): the thumb-screws
- b (left ring, left and right): the sockets
- e (diagonal bar, by its hole at the top end; read in the Toronto copy), d (diagonal bar)
- [?] (upright bar, by its hole at the top; e or c), d (upright bar)
- f (assembled instrument, top and bottom of the cut-out disc); m (tops of the two uprights); g (point of the disc's cut-out); a (ring, upper right and front); c (left and right knobs, bottom knob); b (left and right sockets)
- d (on each of the two uprights of the assembled instrument; read in the Toronto copy)
- o (hook at the end of the thread); l (the plumb-bob)
- r (two corners of the half-disc); n (middle of its straight edge)
- k (outer rim, top and bottom); h (inner ring, top and bottom); i (point of the cut-out); m (the two pivots)
- f (separate disc, top and bottom); g (point of its cut-out)

Two small sockets b are to be attached to either side of this ring, so that two little arms d can be inserted into them when need requires, moved up and down at will, and drawn further out, and can then be secured again, without any difficulty, by applying those two thumb-screws b. [Margin: The construction of a certain instrument by which longitudes and eclipses can be recorded in a far from common way.]

2. In addition, let another small disc f be made, having two poles m about which, supported by those little arms d, it can turn round freely and with no trouble at all.
3. Let this disc f be built of four parts, so that within it a semicircular plate q, n, p, q can be carried round very easily by means of a plumb-line l, and be set upright perpendicularly at any position of the tube whatever. This can be done without difficulty as follows. Let a circular plate h, very like f in form, be surrounded by a band of small width; to this disc h a ring k is then to be fixed, on which another circular plate f can be laid and firmly shut in, while some free space remains inside.

4. Let the very thin semicircular plate p — or, which is better for certain reasons, you will make it so that it somewhat exceeds a semicircle, as you see here — having a small pin passing through its centre n in place of an axis, be inserted into that first disc, so furnished and, as it were, hollowed out inside; in such a way that these pins pass right through the centres i and g of the discs h and f. For in this way that semicircular plate p will be carried freely round in a circle, provided the space within which it has to move is wide enough, and the holes in which those poles are enclosed are likewise smooth enough.
5. When these parts have been neatly prepared in this way, let a plumb-line l of no small weight be hung, by means of that little hook o, from the revolving plate that is more than a semicircle; and so that this may be done easily and as quickly as possible, have two small holes q made in the plate, one at each end.
6. When the plumb-line has been hung and the whole instrument fixed to the telescope by means of the three thumb-screws, you will notice two motions in particular that are proper to this instrument: first, a motion parallel to the horizon, by means of the axis m; second, a certain vertical, or perpendicular, motion by means of the pin n. With the help of these motions, the straight side r r of plate p will continually represent the perpendicular at any position or elevation of the tube whatever.
7. Therefore, with the eye applied to this instrument, which is firmly

attached to the telescope, and with free movement left to the perpendicular revolving plate, contemplate the face of the Moon and her spots carefully. Then note which spots appear to stand entirely upright in a perpendicular line by the rule of the side r r of this plate — which this armed eye is permitted to judge quite accurately and distinctly. At the same moment at which you find two spots so placed, let the altitude of some fixed star be observed at the same time by the work of another person, and let it be carefully recorded together with the names of the spots standing perpendicularly upright.

8. Since, however, the Moon is found, because of the daily motion, in continual inclination from her rising right up to her setting, it comes about that different spots, one after another, continually present themselves under the perpendicular line. It is fitting, therefore, not to be content with one observation, but to obtain with the greatest care very many spots of this kind, each with its corresponding altitude; and this to the end that, if another observer, under some different latitude of place, had not been able to find the earlier spots so placed, it would then without doubt still have been open to him to record at least one or another of the later ones.
9. In connection with these observations, two different things occur that are most worthy of wonder. [Margin: Paradoxes.] First, that although the revolving plate described above covers half of the pupil, it nevertheless does no harm at all to the sight, nor causes any loss. Second, that we

always perceive by sight the part of the object that is covered by the plate, and, on the contrary, do not see at all the part that lies open. For example, if that plate hangs on the right while we are looking at the Moon, then we certainly see not her left half, as by rights we ought, but the right — that is, the covered one. But where does this appearance take its origin, and how does it come about? To some, perhaps — especially those ignorant of optical matters — it will seem a matter of great moment — namely, to determine the true reason for this paradox straight away, at first sight. Let them therefore, if they wish, go to the opticians, who among other wonderful phenomena will make this one too plainer to them;

since the plan of my undertaking does not permit me to treat and demonstrate this at greater length in this place: for we shall now pursue further the matters that must be attended to in our observation of longitudes.[22]

10. If, however, mathematicians should in future value this method of investigating longitudes, as we have explained it, so highly that they decide to undertake the task with its help, then it will above all be supremely necessary that all observers first set about constructing for themselves a Table of the Angles of the vertical and of the Moon's orbit, for every degree of the ecliptic, and indeed for the very horizon at which the observations are to be made. The purpose is that no one should be unaware, with the help of this little table, at what time such observations ought to be undertaken. That happens, of course, at the most opportune time when the angle already mentioned varies as fast as it possibly can; by contrast, the sunspots are observed at no other time better than when the angle of the vertical and the ecliptic changes very little. For the angle of the Moon's orbit and the vertical varies — more at one hour, less at another — as is known to students of the stars. At the time, therefore, when that angle is subject to a greater and faster variation, it will be opportune to investigate longitudes more accurately. [Margin: To find longitudes it is necessary that a Table of the Angles of the vertical and of the Moon's orbit be constructed.]

11. It is also necessary that astronomers fix and agree among themselves certain days on which they are not unwilling to undertake such observations each month under a clear sky, and to continue them at all times; otherwise one would take up this labour on this day and another on another, and if that happened they would certainly lose all their effort. For to keep watch for observations every single day, whenever the sky permits, would truly be a most tedious task. It is therefore only to be wished, as we said just now, that certain days be decreed for carrying out the observations. For example, if those versed in the matter so decide, it will not be unfitting, I think, to give time to observations first at the time

[22] this sentence begins at the foot of PDF p. 666.

of the waxing quadrature; then on the last day before and the first day after opposition; and likewise at the time of the waning quadrature. If everyone agreed on this, then certainly the labour of any observer would very rarely be in vain; indeed, it is certain that great benefit could flow from it, within a short space of time, both to astronomy and to geography. [Margin: Let fixed days be set for undertaking observations.] [Margin: At what time is it more fitting to apply oneself to observations?]

12. It will also contribute not a little to this business if certain lunar spots were prescribed and chosen which ought to be observed in preference to the others, so that one observer would not attend to these and another to others. In my judgement, the following, because of their most convenient position and greater prominence, will be very well suited to these observations: 1. Lacus Niger Major and Mons Ætna. 2. Mons Ætna and Insula Creta. 3. Mons Ætna with Mons Sinai. 4. Lacus Niger Major with Insula Corsica or Vulcania. 5. Lacus Niger Major with Insula Besbicus. 6. Mons Serrorum, likewise with Insula Besbicus, or Byzantium, or Insula Cyanea, or Insula Apollonia; and other very conspicuous spots like these, which observation itself will readily reveal to us. [Margin: Which spots should be attended to above all in the business of observing longitudes?]

13. When, therefore, observations have been carried out accurately in this way in different regions, continually repeated, and compared with the observations of others, it will soon become clear whether the longitude derived from them always comes out consistent with itself. For if that happens, it is a sure sign that the method of observing is most certain, and that the observations too have been made with the greatest possible diligence, so that there need be no doubt at all about their certainty. Besides this, however, there still remains another way of examining the method set out above; if it is not neglected, any error that may have crept in will be detected easily and without difficulty. This is, namely, if two well-practised observers who wished to test this method were to agree, in two widely separated regions and meridians whose difference was already very well known from observed eclipses, to explore the difference of longitude by the way now taught, and to learn whether the later observations, obtained by means of the Moon's spots, correspond entirely to the earlier ones found by eclipses. For if they found no difference whatever, it would be an infallible argument that our method, now commended to the learned world, is most certain; but if some difference were nevertheless noticed (which I scarcely expect, provided only that the observations are carried out skilfully and accurately, as the seriousness of the business demands), it will be necessary for us to take pains that by new inventions this method [Margin: How can the method of investigating longitudes just explained be examined?]

can make more certain and more secure. I have no doubt, however, that in this way the longitudes at least of places far distant from one another can

very well be investigated; as for the rest — whether it is possible to explore the difference in longitude of nearer places equally well as that of more remote ones, or not — experience will teach us. Again and again, however, it must be noted about this practice that, unless observations of this kind are carried out by assiduous and most diligent observers, attentive even to all the smallest details, and equipped with a telescope of the most perfect quality, it will be impossible for us to reach the goal we have set ourselves (as can be seen in eclipses too).

14. From what has been briefly said, then, it will be clear to anyone, I judge, how it is not impossible for longitudes to be explored by different observers at different stations. Now it would likewise be desirable that all and every one, living in any place whatever, could conveniently investigate this at every time, straight away, from a single sight of the Moon's spots. In this way, surely, the greatest service would be done not only to astronomy and geography but above all to navigation, since sailors crossing that great ocean could on any clear night seek with certainty from the Moon's face what they otherwise attain only with great labour and by conjecture. Since this invention has so far escaped us and promises immense benefit, it certainly deserves that everyone leave no stone unturned, so that we may at last one day rejoice in it. And although we may not have hit the mark exactly at the very first attempt, we shall nevertheless surely deserve praise, because, according to our slender means, we have not refused to contribute our zeal and effort to this business and to the public welfare. In great things, even to have willed is enough. And since this too keeps coming to my mind, I shall therefore, as far as the feeble powers of my intellect extend, come to the aid of this endeavour.

First, I hope that, in my judgement, this business will succeed not at all badly if yet another table is first constructed — namely, of the inclination of the disc, or of the Moon's spots, for each degree of every sign and for any hour of the day; and also, if possible, no less for half-hours and quarter-hours [Margin: To investigate longitudes from a single station, at any time and place, by means of the spots.]

and, indeed, for the horizon of Uraniborg[23]; so that, with the help of that table — once the true place of the Moon is known and the day and hour are given — we may not fail to explore the true inclination of the Moon at Uraniborg for that time. For it cannot escape you, my reader, that because of its diurnal motion the Moon continually inclines itself now one way, now another, as has already been impressed upon you many times; and it does so in such a way that on every different horizon it shows us a different inclination, or face. Hence the Moon, at this hour, is inclined thus on our horizon, but otherwise on another, so that a perpetual difference is observed. But to explain my meaning more fully: you should know that by the Moon's inclination I

[23]this phrase begins at the foot of PDF p. 669.

understand that degree of the Moon's limb which is vertical at a given time. This vertical degree of the Moon's limb, I say, corresponding to every time, is to be computed — for the horizon of Uraniborg, that is — and entered in its proper place in the same table that is to be constructed. How the vertical degree just mentioned is found by means of the *Plenilunium versatile* we taught in chapter 26, to which I refer the reader.

Secondly, once this table has been constructed so accurately and set out correctly, our observation will then be arranged as follows. On some clear night, likewise at whatever hour you wish (though it is better to do this around the Moon's rising or setting, because the change of inclination is then faster), you will study the Moon carefully: that is, with the help, moreover, of a telescope fitted to a perpendicular instrument, you will watch diligently for the moment when any two notable spots form an entirely perpendicular line; and at that very moment you will at the same time take the altitude of some fixed star, from which, together with the altitude of the pole, you will accurately derive the time of the observation by trigonometric calculation. Having established this, look up further, with the help of the two spots noted in the *Plenilunium versatile*, as you learned in chapter 26, the degree of the Moon's limb that was vertical at that time. Next, from the ephemerides — if, that is, to save time, you do not wish to compute it from the tables of perpetual motion — likewise look up the true place of the Moon, both in longitude and in latitude. When this too is known, go with this true place of the Moon to that table of inclination, and

thus — by no means neglecting the proportional part, if it is needed — find at what hour that same degree of inclination, or vertical degree of the limb, is found at Uraniborg. If, for example, you find that it occurred at the twelfth hour, but you observe by means of the spots that it happened at the tenth hour, that will be a sure sign that the difference of the meridian of the place where you made the observation is two hours, and indeed that the place is that many hours more easterly than the meridian of Uraniborg, since the spots came to the perpendicular sooner than at Uraniborg. When, however, you find that it happened later, you judge quite correctly that this place is more westerly than the other.

By this method, at any rate, any person at all — and he alone, using no other observations — with an optical tube equipped with a perpendicular instrument, cannot fail to investigate longitudes by means of the lunar spots, on any clear night (provided, that is, the Moon is shining with sufficient light) and at any hour he wishes; but on this express condition: that the observations are carried out with exquisite care by a practised observer who possesses the table of inclination for the meridian of Uraniborg. It will indeed seem to the reader that constructing such a table calls for no small skill and labour; but be that as it may, it can nevertheless be very well accomplished — indeed it deserves to be completed — provided that the method of investigating longitudes described above has found favour with mathematicians. And although the table will turn

out very large, on account, namely, of the varying latitude of the Moon and the retrogression of the nodes, nevertheless with diligence and perseverance this labour too will easily be overcome by tireless calculators of astronomical matters. For who does not know that equally difficult works were completed in earlier times — truly gigantic ones, such as, among others, the various ephemerides of many years and the perpetual tables; to say nothing of the famous *Opus Palatinum*, the great canon of logarithms of Flaccus, and others — so many that, if each and every one had to be listed, time and paper would surely almost run out? Why, then, should a table of this kind not be constructed as well, especially if it is not unable to serve the benefit and profit of learning and of the whole world? But if, against expectation, no one comes forward who dares to undertake this labour, then certainly

I too freely promise my own effort in this matter, provided God grants me life and health; for I am thoroughly convinced that this burden will be much lighter than this very selenographic one, which I took upon myself with God's help.

[Margin: Another method of finding longitudes.]

It follows, indeed, that we should explain another method of investigating longitudes as well. Although in my opinion it is somewhat inferior to the former, I shall nevertheless show that the difference of meridians, especially in remote places, can be explored by this method no less than by the one above. This method will be furnished to us by the inclination of the Moon's horns, carefully observed. For since these too, in the waxing phases, continually decline more and more toward the horizon, and, on the contrary, in the waning phases raise themselves up more and more, it is surely to be hoped that something certain can be determined in this way too — provided only that the inclinations of the horns are observed very accurately, as indeed they must be, since the whole matter turns on this point. How this determination of the inclination ought to be arranged I shall now explain at once.

First, in my judgement, it can be done quite successfully with the help of a hanging astrolabe, if its rule is directed exactly to the inclination of each horn; or secondly — which is almost the same — by means of a semicircle fixed to a tripod: when its diameter, or its line, is inclined correctly toward the horns, then the suspended plumb-line will at once show how great the inclination is in degrees and minutes — that is, the inclination of the upper horn from the Moon's vertical point. If this inclination of the horns is observed several times on one day (especially at the time when the inclination is most variable of all), together with the altitude of some fixed star, in order, that is, to derive the true time; and likewise in other regions, by different observers; I have no doubt that something no less certain can surely be drawn out in this respect. Indeed, even a single observer — having noted this inclination properly and duly several times, having found, with the help of the *Plenilunium versatile*, the degree of the Moon's limb that was vertical at about that time, and having recorded the time correctly from the altitude of some fixed star — will likewise, by this method,

go on to disclose the longitude of any place from that table of the inclination of the lunar spots that is to be constructed for the horizon of Uraniborg.

For observations to be set up in the way just described, it will likewise be very necessary for those skilled in astronomical matters to prescribe and fix certain days on which they are to be carried out. In my opinion the days most to be chosen are those that follow the first appearance, up to the first quadrature, and again those that succeed one another in order from the last quarter up to the last appearance. This investigation of the inclination of the horns will be explored almost more precisely with a spyglass fitted with that perpendicular instrument; and all the more so if you attach to this instrument a semicircle divided into degrees, so that, when a revolving perpendicular blade [lamella] is directed to the inclination of the horns, the plumb-line hung from it can at the same time indicate the degrees and minutes.

[Margin: The third method of investigating the longitudes of places is disclosed.]

It remains, moreover, for me to set out briefly a third method as well of examining longitudes, which, if you see fit, you will undertake in this way. Look at the waxing Moon through a telescope, at whatever time you like, and above all contemplate carefully the boundary of its light and shadow — that is, the moment when the summit of this or that notable mountain is first illuminated by the Sun; and at the same time you will note that moment of time from an altitude or, if it cannot be done otherwise, from some corrected clock. Conversely, if the waning Moon is observed, you must watch for the moment when this or that mountain is completely cast into shadow. This, in my judgement, can be done much more surely than to judge with certainty the first illumination of the peaks of the mountains. For consider for yourself how easily no small error, and very great confusion, can arise from this very thing — that you seize upon an illuminated peak quite other than the one you intended. In the waning phases, by contrast, nothing of the kind is in the least to be feared, since the very thing whose last appearance one intends to watch is before one's eyes. There is also this: the latter may be undertaken whenever it seems good, whereas for the former, which must be pursued through the waxing phases, it is sometimes necessary to spend a great part of the night — which would surely be too burdensome for every observer without exception, however patient he may be of labour and night-watches. Furthermore, it is to be noted that, no less, for this method of exploring longitudes

certain spots should be named by the mathematicians, to which alone all observers should direct their eyes at a fixed, appointed time. It would therefore be altogether advantageous that not many but very few spots — namely those most prominent among all the rest — be assigned to this task, so that when they then come into view every observer without exception may turn his eye to them the more eagerly and readily. For if no definite spots were named, and all were attended to indiscriminately, it could happen that now one observer would seize on one spot and now another on a different one; and by this

astronomy and geography would afterwards be in no way served. For this reason I would think that, among the others that are very conspicuous, these spots should be chosen because of their more convenient position: 1. Insula Major Caspii. 2. Montes Macrocemni. 3. Mons Serrorum and Mons Carpathes. 4. Insula Besbicus. 5. Mons Sipylus and Mons Didymus. 6. Mons Sinai. 7. Lacus Niger Major. 8. Mons Ætna. 9. Insula Creta. 10. Mons Porphyrites. For if these are assigned and laid down for this work, an observation could be expected almost daily at any phase whatever.

This is all we wished to say, briefly, about those three different methods that occurred to our mind for investigating the longitudes of places by means of the Moon's spots. Everything could certainly have been treated more fully — especially if we had wished to give the foundation and the procedure for constructing the table we spoke of, and also a fuller description of the instruments, namely of the hanging astrolabe and of the semicircle fitted with the perpendicular device mentioned above. But since we are aiming at brevity, and the time is almost upon us to bring this particular Selenography to an end altogether, these matters are deferred to another place. Then too, I think, we must first await the judgement of more experienced men on what we have now set out. If they think what has been put forward worth so much that they wish it to be illustrated in a fuller commentary, I candidly promise that, with God's help, I shall write a special little work to that end, both gladly and at the very first opportunity.

[Margin: On making an artificial lunar globe.]

Finally, however, before we bring this to a close, a few things must still be added about making a lunar globe, which, I hope, will be welcome to lovers of the stars not only, and above all, for this reason: that in

it each and every lunar spot can be distinctly noticed, and it is at the same time the best means of committing their names to memory; but also because at any time whatever, the natural face of the phase of any day, and also the libration motion, cannot fail to be set before anyone's eyes by that very means, as well and as clearly as possible — that is, how the Moon partly librates about a certain axis, and how its inclination stands at any time. In short, it will be possible to use this globe conveniently in place of the *Plenilunium versatile*. And indeed all this seems to us no less most useful than most convenient for observations of the Moon's eclipses and occultations of stars, and in part also for investigating the longitudes of places.

[Margin: Its construction.]

I. Concerning the construction of this artificial globe, these points among others are to be noted. 1. That the lunar spots be shown on this globe in exactly the way you see them sketched in the general selenographic table of the phases, R. 2. That suitable names be added to the individual spots. 3. Likewise, that this globe be surrounded by a brass ring divided into its degrees, like the meridian of a celestial or terrestrial globe. You should know, however, that this ring differs from the celestial globe in this respect: it represents not the meridian

but rather the horizon; hence, in my judgement, it will rightly be called the horizontal limb [limbus] of the Moon. In this circle, as is usually done in other artificial globes, the poles must be fixed; about them a smaller circlet, furnished with an index and divided into certain small parts, is to be applied, so that by its help the libration of the Moon can be displayed for any given time.

II. Besides this, however, we need no other horizon here — except that yet another ring, of bronze [annulus æreus] and divided into degrees, should be made to encircle the former horizontal limb completely. But it is not at all necessary that it be joined very tightly to the former; rather, what matters is that it be somewhat larger — large enough, that is, for the index on the smaller circlet, which is applied to the horizontal limb, to be carried round freely.

III. The latter brass limb will serve so that the globe, together with the other limb that surrounds it and the circlet fixed at the pole, up and down without any hindrance

III. The latter brass limb will serve so that the globe, together with the other limb that surrounds it and the circlet fixed at the pole, can be moved up and down without any hindrance, and this for setting up and representing the vertical degree of the lunar limb and its inclinations at a given, definite time, and indeed in any horizon whatever.[24] And yet the larger ring already mentioned performs almost the same function as the outermost circle does in the *Plenilunium versatile*. But so that this globe may do its work all the better, it must be firmly supported on a stand of some kind.

IV. The smaller circlet with the index, already mentioned above, is not used to show us the hours or the quarter-hours, as is usually done on others; rather, it is used so that the celestial signs, divided into definite parts, may be transferred onto it, and also so that with their help, once the true place of the Moon is known, the libration motion corresponding to any time may be displayed, as we have just said — by quite the same method by which we taught earlier how to describe the Moon's limb from those various marked centres with the help of the primary figure of the full moon.

V. Let a meridian, or a kind of movable vertical circle, also be fitted to this lunar globe, like the quadrant of a celestial and terrestrial globe — even though this one differs somewhat from that one, in that that one is a semicircle and this one a quadrant, and also that one is fixed at the points of the zenith and nadir. This is done with the following end in view: that phases of every kind, and of any time whatever — that is, whether past or future — may be set before everyone's eyes; just as any spots lying on the boundary at this or at another time may also be indicated by name; and likewise which brightly illuminated cusps, at this or that part of the boundary, will be visible in the darkened part of the Moon at this or that time; or at what place of the section between the luminous and the shadowy part this or that cusp ceases altogether to be illuminated — to say nothing of a great many other things of this kind. Finally, above all

[24] This sentence begins on PDF p. 675.

else, you will notice on this lunar globe, as something most singular, that one hemisphere appears almost bare of spots. This happens because, of course, we can by no means see the greatest part of the lunar hemisphere that is turned away from us. That hemisphere, then — empty, as indeed it is — will be the Moon's unknown land [terra Lunæ incognita]. But so that this half may not remain altogether empty,

it will be permissible, if it seems good, to fill it with certain notes and precepts. And indeed, if we were not short of time, and if the moment at which the sails of this *Selenographia* must be furled did not already seem to be approaching, I would not in the least hesitate to present to the world, together with this very work, a material globe accurately constructed in the form just indicated, with an explanation added that would be both fuller and plainer. Since, however, this cannot be done at present because of the various labours that hold us, we shall reserve both this very thing and certain other, much more specialised matters, which it was not convenient to touch on here, for some more suitable occasion. Farewell now, reader, devoted both to me and above all to celestial things; and please look with a fair eye on the figure of the lunar globe that I add.

Diagram. An engraved plate of the lunar globe described above. The globe stands on a turned baluster pedestal with a stepped round foot, which casts a shadow to the left. Its upper part shows a light patch with dotted outlines; the rest of the sphere is shaded. Around the globe run a broad graduated ring and an inner graduated ring, both numbered at intervals; a graduated arc runs from the top of the ring to its foot across the front of the globe; and a small circlet with an index is mounted on the ring at the left.

- No letters, caption, place-names or engraver's line are engraved on the plate.
- Scale numerals on the two rings and on the arc: not read.

THE END OF THE *SELENOGRAPHIA*.

SELENOGRAPHIÆ APPENDIX; ET HELIOGRAPHICAS ALIQUOT ANNORUM OBSERVATIONES, ET ORBIS JOVIALIS POSITUM, MOTUMQUE EXHIBENS.

An Appendix to the Selenographia, presenting heliographic observations over several years, and the position and motion of the orb of Jupiter.

AD LECTOREM.

To the Reader.

Now that the *Selenographia* has, with God's help, been brought fully to its end, it remains for us, friendly reader, to make public by way of an appendix the observations of the sunspots and also of the Jovials, as we gave hope above, in Chapter 5. In this way anyone, and one eager for the science of the stars, may grasp all the better and the more easily, by inspecting such observations with his own eyes and by their demonstration, each and every thing that was set out in that chapter on the rising and setting of the spots, both astronomical and physical, on their different kinds, on how they move with a motion that varies yet keeps a wonderful constancy, and on other matters belonging here. And he may at last conclude with us (notwithstanding the inveterate dogma of the Peripatetics) that generation and corruption, increase and diminution — and indeed sometimes truly wonderfully great — exist in the very bowels of the heavens. This will shine out clearer than the light of the Sun from the periods of the solar spots and faculae, observed up to now and always to be observed.

From this it also becomes likely to us that even those who are complete strangers to mathematical matters will come round to our opinion, provided that they have turned their eye and mind in some measure to these observations of ours — unless, led only by the authority of a name and by some quip or other, they prefer (not very philosophically, I think) to err with the Philosopher rather than to embrace the truth and judge rightly.

We did not, however, think it advisable to set down here only the bare and simple observations, since little benefit would then flow from them to the reader: they would be like geometrical demonstrations with no letters added to mark them. Sparing no effort, therefore, we have added to each figure of

the sunspots certain annotations, brief and as concise as could be, but such as will give the understanding light enough; so that we think hardly anything more can rightly be asked of us. We took the same care, above all, over the observations of the Jovials. For, first, in each of the figures you will see marked the position, distance, size and proportion of the stars, both to one another and to Jupiter. Second, on the facing page you will read what is most worth noting about each observation. From this, indeed, the motion of these four planets and companions of Jupiter will also be established more and more firmly, and the teachers of the mathematical sciences will be given a most welcome opportunity of constructing perpetual tables from these and similar studies. And also, if such tables have perhaps already been composed by some, they will be able, if they wish, to put them to this test to excellent effect, considering whether they agree altogether and in every respect with the rule of truth; for if even some difference is still detected, it will be easy to correct them.

That this may turn out well, as everyone wishes and for the common good (this work of ours bringing some benefit to the growth of mathematical studies), we pray to God from the heart: and that, by the singular grace of the same Best and Greatest, many more and more hidden things, of greater moment and of most thoroughly tested truth, may not fail in time to become known to us, to the glory of His name and the fuller knowledge of His works, and be brought out into the light[25].

Animadversiones super I. Macularum Solarium periodo.

Remarks on Period I of the Sunspots.

1. In the year from the birth of Christ 1642, on October 26, no spots at all appeared on the Sun.
2. October 27: the sky was not favourable.
3. October 28: I noticed a large, oblong, dense and very beautiful spot, a, surrounded on all sides by a halo of no ordinary kind; apart from this one, however, nothing whatever was detected on the Sun. [Margin: A remarkable spot appeared, crowned with a nimbus.]
4. October 29 and 30: because of the turbulence of the air it was not possible to observe that notable spot seen on the day before.
5. October 31: for the second time it fell to us to see the spot mentioned above, but in a larger form and furnished with two very dense nuclei.
6. November 1: that same spot had changed not at all, either in shape or in brightness and size.
7. November 2: no sun shone.
8. November 3: it had not only advanced further towards the west on the Sun's disc, but was also turning more and more towards the north.
9. November 4: it appeared not at all changed as yet.
10. November 5: the harshness of the sky prevented observation.

[25]printed «protahantur», with no r after the t; read as protrahantur

11. November 6: it seemed a little more oblong; and then, near the rising side [circa ortum], three new, smaller spots were seen, which are kept for the following figure.
12. November 7: the air was cloudy.
13. November 8: I would very gladly have observed the exit of this remarkable spot, but it was in vain, for it had already gone out, so that not a trace of it appeared any longer at the periphery. As to the spot's course, so far as can be gathered, it lasted only 12 days. Moreover, it is more than clear from this motion that the path of this spot was concave towards the north [Aquilonem Borealem] and convex towards the western south [Austrum occidentalem]. [Margin: The spot spent 12 days on the Sun.] [Margin: By what path did it travel?]

Diagram. An engraved plate inside a plate-mark: a large circle, the Sun's disc, cut by a horizontal diameter marked A at the left end and B at the right, with "Ecliptica" written beneath it near the centre. Six spots stand along and above the line, rising slightly towards the right; each carries the letter a above it and a day-number below it. A three-line caption is engraved at the head of the disc, and a small table of observations stands in its lower half. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Caption (head of the disc): "GEDANI. Anno æræ Chriſtianæ, 1642. Curſus Maculæ, à 28 Oct. ad 6 Novemb." — *Danzig. In the year of the Christian era 1642. The course of the spot, from October 28 to November 6.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Below the diameter: "Ecliptica." — *The ecliptic.*
- Above each of the six spots: a
- Below the spots, left to right: 28, 31, 1, 3, 4; below the sixth spot (upper right): 6
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left: "fig. H H."
- Lower right: "Autor Sculpſit." — *The author engraved it.*

October. November.

Day (D.)	Hour (Hor.)	1.		Ang.	′
28	10	28	m.	56	25
31	9	20	m.	47	52
1	9	23	m.	49	3
3	9	53	m.	53	17
4	9	56	m.	53	58
6	9	0	m.	48	10

26

Diagram. An engraved plate inside a plate-mark, laid out like the preceding one: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica" written beneath it. Above the line stands a train of spots rising gently from left to right, labelled with the letters b and c and with day-numbers; at each limb a spot sits inside a hatched patch. The numeral "II." is engraved at the upper left outside the disc, a three-line caption at the head of the disc, and a table of observations in its lower half.

- Upper left, outside the disc: "II."
- Caption (head of the disc): "GEDANI. Anno æræ Chriſtianæ, 1642. Curſus Macularum, à 6 ad 17 Novemb." — *Danzig. In the year of the Christian era 1642. The course of the spots, from November 6 to 17.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Below the diameter: "Ecliptica." — *The ecliptic.*
- Spot labels, left to right: b over a spot at the left limb in a hatched patch, with 6 below the diameter; c over 6, stacked, at the upper left; b over a spot with 8 below it; b with 9; c over 8, stacked; b with 11; b with 12; b with 13; b with 14; b with 15; in a hatched patch at the right limb, a faint letter, perhaps b [?], with 16, and b with 17
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens:" — *B. West.*
- Lower left: "fig. II."
- Lower right: "Aut. Sculps." — *The author engraved it.*

November.

Day (D.)	Hour (Hor.)	l.		Ang.	
6	11	16	m.	65°	52′
8	10	30	m.	59	46
9	10	30	m:	60	5
11	9	48	m.	55	13
12	1	42	u. [?]	88	25
13	10	51	m.	64	48
14	12	8		103	48
15	11	52		74	10
16	12	0		75	42
17	11	42		78	15

Animadversiones super II. Macularum Solarium periodo.

Remarks on Period II of the Sunspots.

1. November 5: the sky was overcast with clouds.

[26] the legend reads «fig. H H.» (lower-case swash f); the letters H H are confirmed, and they stand in series between GG and II.

2. November 6: only a single spot, c, was seen, crowned with shadows and mists; but at 11^h 16 min. two more, smaller and weaker, presented themselves, and I am certain that they were first born on the Sun's disc at that very time.
3. November 7: because of the inclemency of the air we could note nothing.
4. November 8: four spots appeared, with a much more splendid retinue of faculae and shadows lying near the eastern horizon. The last spot of all was the largest; of the remaining three, the middle one, newly risen, looked very diffuse and weak.
5. November 9: of the 4 spots observed on the previous day, only the largest still survived; the rest were completely extinguished. And although the sky was clear, not even the slightest trace of them was noticed. From this it is clear enough that these spots had not passed beneath the Sun [Solem … subingressas], but were born and dispersed in the middle of its disc. The faculae and shadows, however, held almost the same place near the horizon as on the eighth day. [Margin: Spots are sometimes generated and destroyed on the Sun's disc.]
6. November 10: the sky was cloudy.
7. November 11: spot b was detected, thin and weak; but faculae and shadows were no longer present at all.
8. November 12: to my very great astonishment I noticed that from one thin and diffuse spot two larger and denser ones had been produced. [Margin: From a single spot two were produced.]
9. On the 13th the two already mentioned were equal.
10. On the 14th the same two were still fairly conspicuous.
11. On the 15th those two smaller spots appeared weaker.
12. On the 16th the preceding one of these two was so attenuated that it could barely be made out at all.
13. November 17: a single spot only appeared, near the horizon, surrounded on all sides by shadows and faculae. These spots travelled across the Sun in 13 days, along a curved path convex towards the south. [Margin: Course of the spot over 13 days.]
14. November 18: nothing whatever was detected on the Sun. [Margin: The Sun observed entirely free of every spot.]

Animadversiones super III. Macularum Solarium periodo.

Remarks on Period III of the Sunspots.

1. May 22: we saw six spots on the Sun. Of these the hindmost, a, was the most notable, by reason of its size and its very dense nucleus; the remaining three, c, in the more westerly part of the Sun, were seen to be both smaller and weaker.
2. May 23: spot a appeared rounder and girt with a halo. From those three c, moreover, five had now been generated; but the two very weak ones,

b, had by now been completely dispersed. [Margin: From three spots 5 were born.]

3. May 24: there was no opportunity of observing anything.
4. On the 25th we again saw four spots, but presenting an entirely different form or shape. a had grown a very little; but those five c had been reduced to one, and that a very weak one. [Margin: Conversely, 5 spots coalesced into one.]
5. On the 26th, besides the others visible on the Sun, a new spot, e, presented itself once more to our notice near the rising horizon, but thin and very diffuse.
6. On the 27th the sky was cloudy.
7. May 28: nothing more appeared of that smaller, newly risen spot e; and the rest too had been attenuated not a little in brightness and bulk. [Margin: A spot of two days.]
8. May 29: only two, namely a and b, were still present; the others had vanished entirely.
9. On the 30th of the same month, spot b, because of the thinness [raritatem] of its body, scarcely met the eye; the other, a, was still fairly dense.
10. May 31: only spot a was still moving near the setting side, for b had already gone out of the Sun's circle [orbitâ].
11. Near their exit the course of these spots approaches a straight line; and anyone can see this by a closer inspection of the present figure. [Margin: Near the setting, the course of the spots approaches a straight line.]

Animadversiones super IV. Macularum Solarium periodo.

Remarks on Period IV of the Sunspots.

1. From June 9 to the 17th of the same month, nothing could be observed.

Diagram. An engraved plate inside a plate-mark in the upper part of the leaf, laid out like the two before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica" written beneath it. Lettered spots, each with a day-number, are strung across the disc from the left limb to the right, most of them above the diameter and drifting down towards it on the right; two groups of spots are ringed with dots. A three-line caption stands at the head of the disc and a table of observations in its lower half. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Caption (head of the disc): "GEDANI. Anno æræ Chriſtianæ, 1643. Curſus Macul⟦a/o⟧rum, à 22 Maij ad 31 eiusdem" — *Danzig. In the year of the Christian era 1643. The course of the spots, from May 22 to the 31st of the same month.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Below the diameter: "Ecliptica." — *The ecliptic.*

- Spot labels, left to right: e with 26, near the left limb; a with 22; a with 23 (spot ringed with dots); b with 23, over two small spots; a with 25; b with 25, the figure to the left of a small spot; a with 26; b with 25; c with 22, over a dotted group just above the diameter; d with 26; d over a small spot with no figure; 25 beside a large spot, and a over a second large spot beside it, with 28 below the pair; c with 23, over a dotted group below the diameter; d with 28; "28 b" set together over a spot; a with 29, on the diameter; c with 25, below the diameter at the lower right; "29 b" set together over a spot on the diameter; a with 30; a with 31; b with 30, at the right limb
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left: "fig KK."
- Lower right: "Aut. Sculpſ." — *The author engraved it.*

May.

Day (D.)	Hour (Hor.)	1.		Ang.	
22	8	54	m.	67°	36′
23	8	10	m.	64	34
25	9	40	m.	72	19
26	8	12	m.	63	17
28	9	24	m.	67	52
29	8	22	m.	63	6
30	8	7	m.	61	26
31	9	42	m.	68	41

Diagram. An engraved plate inside a plate-mark in the upper part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica" written beneath it. A large Roman numeral "IV." stands at the upper left, outside the disc. A large hatched group of faculae touches the left limb above the diameter; from it a row of single spots, a, descends towards the diameter, and a second row, b, runs from a large spot on the diameter to the right limb. Below the diameter stand three small groups, d, in the left half, and five groups, c, descending towards the lower right. A three-line caption stands at the head of the disc and a table of observations in its lower half. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "IV."
- Caption (head of the disc): "GEDANI. Anno æræ Chriſtianæ, 1643. Curſus Macularum, à 18, ad 23 Junij." — *Danzig. In the year of the Christian era 1643. The course of the spots, from June 18 to 23.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Below the diameter: "Ecliptica." — *The ecliptic.*
- Spot labels above the diameter, left to right: e over the hatched group at the left limb, with 19 at its foot; a with 18; a with 19; a with 20; a with 21;

a with 22; a with 23; b with 18, beside the large spot on the diameter; b with 19; b with 20; b with 21, at the right limb

- Spot labels below the diameter, left to right: d with 21; d with 22; d with 23; c with a figure beginning "1" whose second figure is not read [?]; c with 20; c with 21; c with 22; c with 23
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left: "fig. LL."
- Lower right: "Autor Sculpſ." — *The author engraved it.*

June.

Day (D.)	Hour (Hor.)	1.		Ang.	
18	8	5	m.	52°	49′
19	3	48	u. [?]	50	[5 or 6]2 [?]
20	8	23	m.	52	51
21	9	45	m.	59	14
22	7	49	m.	50	35
23	7	50	m.	49	49

2. On the 18th we detected two spots on the Sun's disc. The one, b, was very large and dense and was moving on the ecliptic itself, having by now almost completed the greatest part of its own path; the other, a, near the rising horizon and above the ecliptic, was very weak and faint. [Margin: A large, intense spot, endowed with a splendid nucleus.]
3. On June 19 we detected that spots a and b had changed not only in size but also in form; and, to our very great astonishment, we detected besides another new one, c, fairly large, dense and conspicuous, surrounded by three diffuse smaller ones, born now for the first time in the very middle of the Sun. Moreover, a huge troop of shadows and faculae, e, appeared near the eastern limb. [Margin: In the middle of the Sun 4 spots arose.]
4. On the 20th spot b had changed its shape again, but a not at all; c, on the other hand, had altered itself in a remarkable way. For on the preceding day only a single large one was seen, but now two, notable for their bulk and very dense. The faculae and shadows likewise, spreading much more widely, occupied almost the same place.
5. On the 21st the larger spot b, without companions, was verging towards the setting. Spots c showed a different face day after day, as the figure attests. For they appeared now larger and denser, now smaller and weaker, now more numerous, now fewer; so that on the 23rd they had all been reduced again to one, very faint. The shadows and faculae, for their part, had been entirely dispersed; but in their place three new spots, d, which had not been seen before, came forth below the ecliptic, towards the south. [Margin: Spots changing their form or shape day by day.]
6. On the 22nd that larger, western spot b had by now passed the Sun entirely. Spot a, however, was continuing its course, decreasing as it went. But spots d had grown in number and size.

7. What position and form those spots had on the 23rd is plain from the attached diagram.
8. On the 24th, at 7^h in the evening, there was indeed no opportunity of observing the spots accurately, only of seeing them. By that time a had already passed away entirely into nothing before it reached the horizon; c likewise was no longer to be seen. [Margin: Spot a extinguished within the Sun's circle.] Moreover, those two spots d were seen both equal in size and further apart from each other. Besides, two new ones, recently born on the Sun's disc, appeared above the ecliptic, verging towards the north; on the preceding day, although the sky was most favourable, not even a trace of them was noticed. [Margin: Others again born there unexpectedly.] And from this it follows by a certain law that these spots had not entered the Sun, but were generated entirely in it. Of these, however, as also of spots d, we shall show a special figure, M M, which follows. As for the path of spots a, b and c, it was curved inwards, as you see from the adjoining figure, namely towards the north-west, as always happens at a like season of the year. [Margin: Curvature and inclination of the path.]

Animadversiones super V. Macularum Solarium Periodo.

Remarks on Period V of the Sunspots.

1. Concerning the rise and progress of spots d, from June 21 to the 24th of the same month, we have said enough, I think, in the description of the preceding spots. Let us therefore see what the state was, in the following days, both of these, d, and of those, f. [Margin: Spots changed not only in form but also in number.]
2. On June 25, those two spots I had observed on the 24th had resolved into 6, some of which were also fairly conspicuous, as can be seen at the letter f. Spots d, however, were seen both larger and further apart from each other than on the 23rd. [Margin: Spots split into several.]
3. On the 26th we noticed that spots f had varied wonderfully in shape, size and number. And one of them, which adhered to the other, appeared fairly large indeed, but very diffuse and scattered, faint like a weak cloud, so that here and there I could clearly make out the shining Sun through it. The southern spots d had likewise grown in number. [Margin: A very diffuse and scattered spot.]
4. On the 27th no Sun shone.
5. On the 28th spots f seemed to have grown, not in number indeed, but in bulk. Of the five spots e, however, only one still remained. The remaining southern ones, too, had [?] into two weaker and smaller ones. [Margin: Several spots reduced to one weak one.]
6. On June 29 spots f had spread out still further, into more. The lower ones, d, however, had dwindled into very thin shadows and faculae, in

the middle of which there stood a very weak spot, which nevertheless almost eluded sight. [Margin: Spots kindled into faculae.]

7. On June 30 the inclemency of the sky prevented observation.
8. On July 1 we saw only five of spots f. But the faculae had been entirely extinguished. [Margin: Spots f were decreasing in number.]
9. On July 2 no more than 3 of spots f were still visible.
10. Only one of spots f appeared, near the horizon; the rest had partly gone out, partly vanished. These spots f stayed on the Sun only 9 days, since on June 23 nothing at all was noticed of them. [Margin: A stay of 9 days on the Sun.]

Diagram. An engraved plate inside a plate-mark in the upper part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica" written beneath it. A large Roman numeral "V." stands at the upper left, outside the disc. A three-line caption stands at the head of the disc. Above the diameter a band of spot groups, f and e, crosses the disc from the left towards the right limb, where three spots f are tied by leader lines to the figures 1, 2 and 3 at the diameter. Below the diameter a row of seven groups, d, runs from the left half to the lower right, the last of them a large hatched patch. Two tables of observations, for June and July, stand side by side in the lower half of the disc. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "V."
- Caption (head of the disc): "GEDANI. Anno æræ Chriſtianæ, 1643. Curſus Macularum, à 21 Junij, ad 3 Julii." — *Danzig. In the year of the Christian era 1643. The course of the spots, from June 21 to July 3.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Below the diameter: "Ecliptica." — *The ecliptic.*
- Spot labels above the diameter, left to right: f with 25; 26 with f, over a group of two large spots; e with 25, under that group; e with 26; f with 28; f with 29; e with 28, just above the diameter; e with 29; three f at the right limb, with the figures 1, 2 and 3 at the diameter
- Spot labels below the diameter, left to right: d with a figure read as 2, no second figure seen [?]; d with 22; d with 23; d with 25; d with 26; d with 28; d with 29, on the large hatched patch
- Lower part of the disc: "A. Oriens" — *A. East*; "B. Occidens" — *B. West*
- Lower left: "fig. MM."
- Lower right: "Aut. Sc." — *The author engraved it.*

June.

Day (D.)	Hour (Hor.)	1.		Ang.	
21	9	43	m.	59°	30
22	7	49	m.	50	[3 or 8]5 [?]
23	7	50	m.	49	49

Day (D.)	Hour (Hor.)	l.		Ang.	
25	7	35	m.	49	4
26	7	37	m.	48	38
28	9	50	m.	57	34
29	7	50	m.	47	44

July.

Day (D.)	Hour (Hor.)	l.		Ang.	
1	4	34	u. [?]	55°	33
2	8	6	m.	47	2
3	8	0	m.	46	0

Diagram. An engraved plate inside a plate-mark in the upper part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica" written beneath it. A large Roman numeral "VI." stands at the upper left, outside the disc, and a three-line caption at the head of the disc. Large hatched patches (faculae), touched in colour on the scan, stand in the upper left and upper right of the disc, at the left limb, at the right limb on and below the diameter, and in the lower left. A track of single spots, a, runs from the patch at the left limb down to the diameter and along it to the patch at the right limb; three small spots, d, stand near the left limb above the track; a few further spots below the diameter right of centre carry small marks that are not read. A table of observations for July stands in the lower half of the disc. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "VI."
- Caption (head of the disc): "GEDANI. Anno æræ Chriſtianæ 1643. Curſus Macularum, à 7 Julii, ad 18 eiusdem." — *Danzig. In the year of the Christian era 1643. The course of the spots, from July 7 to the 18th of the same month.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Below the diameter: "Ecliptica." — *The ecliptic.*
- Hatched patches in the upper part of the disc: a with 8 (upper left); a with 18 (upper right)
- Near the left limb, above the track: d with 17; d with 17; d with 18
- The track, left to right: a and a on the patch at the left limb, with 7 and 8 below it; a with 8; a with 9; a with 9; a with 11; a with 13; a with 14; a with 15
- Below the diameter, right of the spot a 15: 8b above one spot; c7 below the same spot; a mark below another spot, seen as "b" or "16" [?]
- Patch at the right limb on the diameter: a, a, a, with 17, 17 and 18 below
- Below the diameter near the right limb: 8 under a small hatched patch; 9 under a larger one; no letter seen with either

- Lower left: a with 9, on a hatched patch
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. NN."
- Lower right: "Aut. Sculpſ." — *The author engraved it.*

July.

Day (D.)	Hour (Hor.)	l.		Ang.	
7	6	10	u. [?]	59°	0
8	6	45	m.	44	18
8	5	51	u. [?]	58	0
9	7	18	m.	43	57
9	6 or 8 [?]	34	u. [?]	58	42
11	3	32	u. [?]	61	14
13	7	9	m.	42	20
14	3	23	u. [?]	63	10
15	4	6	u. [?]	62	11
17	7	26	m.	41	6
17	5	19	u. [?]	61	55
18	7	18	m.	40	42

11. On July 4, at 4^h 30^m, we saw nothing of the spots on the Sun's disc, and on the 5th and 6th we detected nothing at all, although the sky was very clear. [Margin: The Sun is found empty of spots.]

Animadversiones super VI. Macularum Solarium periodo.

Remarks on Period VI of the Sunspots.

1. On July 7, at 6^h 10^m in the evening, spot a, very black and highly conspicuous, appeared once more near the rising horizon. At the same time three very weak southern ones, b and c, emerged in the western quadrant of the Sun; these had neither entered the Sun in the usual way nor ever been seen by us before. [Margin: Spots of two days.]
2. On July 8, in the morning, shadows and faculae accompanied spot a, although on the day immediately before there had not been even a trace of them. And of those smaller ones, b and c, only one was still visible; the rest had been wiped out entirely. In the afternoon, however, at 5^h 51^m, the arrangement of the faculae was different; and a small spot was likewise detected under spot a.
3. On the 9th the very weak spot b passed into faculae and finally went away altogether with them. The other faculae, the eastern ones, have been observed continually up to this point, but taking on a different form and shape from day to day. [Margin: A spot observed decreasing at the ecliptic itself.]
4. On July 14 spot a was grazing the ecliptic, and it decreased from day to day until its exit. Moreover, that small companion of the larger spot was seen for the last time on this day, for afterwards it never appeared again.

5. On the 17th a new spot, d, had again entered the Sun; you will find its course in the figure that follows. At the same time, moreover, very brilliant faculae came forth around the other spot, a, and kept their brilliance until that spot a went out. The spot itself, however, decreased little by little, so that near its setting, namely on the 19th, it almost escaped sight. [Margin: Brilliant faculae appeared around the spot at both its rising and its setting.]
6. This spot a lasted from horizon to horizon about 14 days. Its motion, moreover, was curvilinear, and concave towards the north-west; and in that quadrant its arctic pole was rising at that time. [Margin: A course of about 14 days.]
7. Here, moreover, you have points to note. First, that this spot a was one of the returning spots, and was the very same as b shown in figure IV, which had left the Sun's disc on the morning of June 22. The place, the time, the motion and the same parallel certainly suggest this. For it entered the Sun the second time at exactly the place where it ought by right to have entered. This spot does indeed seem to have been nearer the ecliptic at its rising than at its earlier entry; but that follows necessarily from its course and from the advance of the annual pole, inasmuch as that pole now lies in the north-west and is raised more and more from the west towards the zenith point. As a result, the second course of this spot is altogether lower at the rising and raised more and more at the setting. Second, this spot entered the visible hemisphere of the Sun a second time on July 6, so that it is plainly evident from this that it spent about 14 days in the hidden hemisphere; and just such an interval of time is certainly required to make this journey. Besides, it is easily credible that this spot could have lasted so long, since it left the Sun while it was still growing and afterwards re-entered it while decreasing. Third, it can also serve us as evidence that the same spot returned again, that it showed itself once more in its proper form and size, with a small companion, as had happened at its earlier exit. [Margin: A returning spot [?], from all the circumstances.]
8. As to its course, it was curvilinear, and indeed convex towards the south-east, as we have always noticed in the months of June, July and August. This spot, moreover, stayed on its second passage in the visible hemisphere of the Sun for more than 13 [?] days, and in the hidden one, as we have already said, 14, so that in running round the whole Sun it took 27 days. From these reasons it is more than sufficiently clear that spot a, which we have given drawn in the present figure, O O, was altogether a returning spot; and the same can almost be affirmed of spot d, in the figure that follows. [Margin: The spot spent 27 days going round the whole Sun.]

Animadversiones super VII Macularum Solarium periodo.

Remarks on Period VII of the Sunspots.

1. On the morning of July 17 a single spot only, d, appeared. Towards evening, however, another one besides, smaller and weaker, was detected towards the ecliptic, with a huge stretch of shadows and faculae.
2. On the 18th three were seen on the Sun, namely d, f and e, moving along the same straight line. Of these the more southerly, e, had first come into being on the Sun's disc: for on the day before nothing at all had been noticed of it, and yet it now looked the largest of all three.
3. On the 20th spots d and e had increased in size and were more separated than on the 18th; f, for its part, had by now produced two smaller spots; and likewise, at the same time, a very weak new spot, h, was seen, from which, on the following day, the 21st, two much denser ones were produced. These six spots, on this very day, namely the 20th, drew behind them a marvellous retinue of faculae and shadows, while that retinue equalled a third part of the Sun's diameter in length and a ninth part of the same diameter in breadth. This is certainly most worth noting, above all because on the following day every one of them, to the last, went away entirely into nothing again. [Margin: A most remarkable facula.] [Margin: The extent of the facula.]
4. Spot d decreased day by day until, on the 25th, it vanished entirely. Spot e, by contrast, grew until about the middle, and afterwards was gradually thinned again, as you have it marked in the figure. The spots f were seen on the Sun for the last time on the 24th. [Margin: Spot e grew until the middle, then diminished again.]
5. On the 22nd, of the three spots h only two were seen, but larger and denser ones; on the 25th these were again broken up into four smaller ones. Thereafter, namely on the 26th and 27th, only two presented themselves, surrounded on all sides by shadows; but on the 28th these spots and shadows looked to have been entirely routed.
6. On the 26th brilliant faculae arose once more around spot e. On the following day they became much larger and brighter (since this usually happens near the horizon); but the nearer they are to the centre, the thinner and more scattered they appear.
7. That spots d and f were likewise returning spots I am very nearly ready to affirm, from the time and the motion. Since, however, the circumstances do not yet all confirm it sufficiently, I leave this matter for you, kind reader, to judge.

Diagram. An engraved plate inside a plate-mark in the upper part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right; no word is engraved beneath the diameter. A large Roman numeral "VII." stands at the upper left, outside the disc, and a three-line caption at the head of the disc. Large hatched patches

(faculae), touched in colour on the scan, stand in the upper left of the disc, at the left limb above the diameter, in the upper right, at the right limb, below the diameter right of centre, and in a very large mass running from the lower left towards the centre. Spots lettered d, f, e and h, each d, e and h with a day figure, run from the left limb towards the right limb above and along the diameter. A table of observations for July stands in the lower half of the disc. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "VII."
- Caption (head of the disc): "GEDANI. Anno æræ Christianæ, 1643. Curſus Macularum, à 17 Julii, ad 27 eiusdem." — *Danzig. In the year of the Christian era 1643. The course of the spots, from July 17 to the 27th of the same month.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Hatched patch in the upper left: d, f, e down its right edge, with 18 below e
- Patch at the left limb, above the diameter: d with 17; d with 17; d with 18; f with 17; f, no figure seen; e with 18
- On or just above the diameter in the left half: h with 20; h with 21; h with 22
- Across the upper middle of the disc, left to right: d with 20, f, e with 20; d with 21, f, e with 21; d with 22, f, e with 22; d with 24; f, no figure seen
- Below the diameter right of centre: h with 24; h with 25; h with 26 and h with 27, each on an outlined hatched patch
- On or by the diameter towards the right limb: e with 24; e with 25; e with 26; e with 27
- Hatched patch in the upper right: e with 27
- Very large patch in the lower left: d, f, e, with 20 beside e
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. OO."
- Lower right: "Aut. Sc." — *The author engraved it.*

July.

Day (D.)	Hour (Hor.)	l.		Ang.	
17	7	26	m.	41°	6′
17	5	19	u. [?]	61	55
18	7	18	m.	40	42
20	7	47	m.	40	[5 or 6]8 [?]
21	6	30	m.	40	16
22	6	29	m.	39	47
24	7	4	m.	39	7
25	6	45	m.	38	55
26	7	5	m.	38	33
27	7	15	m.	38	22

Diagram. An engraved plate inside a plate-mark in the upper part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica" written beneath it. A large Roman numeral "VIII." stands at the upper left, outside the disc, and a three-line caption at the head of the disc. Two tables of observations, for July–August and for August, stand side by side in the upper half of the disc, under the caption. Above the diameter: a large hatched patch (facula), touched in colour on the scan, in the upper left, with spots b; three single spots b across the middle; a spot d and a hatched patch with two spots d at the right limb. Below the diameter: two spots c and two spots a at the left limb, then a row of ten spots a running towards the right limb, several on outlined or hatched patches, each with a day figure. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "VIII."
- Caption (head of the disc): "GEDANI. Anno æræ Christianæ, 1643. Curſus Macularum, à 30 Julii, ad 15 Augusti." — *Danzig. In the year of the Christian era 1643. The course of the spots, from July 30 to August 15.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Below the diameter: "Ecliptica." — *The ecliptic.*
- Hatched patch in the upper left: b, b above it; 9 and 10 below its two spots
- Above the diameter, middle of the disc, left to right: b with 12; b with 13; b with 14
- Above the diameter towards the right: d with 13; hatched patch at the right limb: d, d, with 14 and 15 below
- At the left limb below the diameter: c, c over two spots; a faint figure 13 below the second c spot; a, a over two spots below them, with a faint figure 30 below the first and 31 below the second
- Row below the diameter, left to right: a with 1; a with 2; a with 3; a with 4; a with 5; a with 6; a with 7; a with 8; a with 9, on a hatched patch; a with 10
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. PP."
- Lower right: "Aut. Sculp." — *The author engraved it.*

July.

Day (D.)	Hour (Hor.)	1.		Ang.	
30	7	31	m.	37°	48
31	7	33	m.	37	36

August.

Day (D.)	Hour (Hor.)	l.		Ang.	
1	7	32	m.	37	21
2	9	49	m.	46	21
3	7	59	m.	37	48
4	7	41	m.	37	0
5	7	49	m.	37	3

August.

Day (D.)	Hour (Hor.)	l.		Ang.	
6	7	45	m.	36°	44
7	7	54	m.	36	51
8	6	30	m.	35	38
9	6	59	m.	35	21
10	7	10	m.	35	19
12	6	38	m.	34	46
13	7	31	m.	34	8

Animadversiones super VIII. Macularum Solarium periodo.

Remarks on Period VIII of the Sunspots.

1. On July 28 and 29 no spot at all was seen on the Sun. On the 30th, however, a single spot, a, was observed in the southern part of the Sun; it grew until about the middle, but afterwards gradually decreased again.
2. On July 3 another one besides, very small, weak and newly born, followed spot a; together with the larger one it was crowned with a nimbus, as also on the following day. Nor was any other difference detected at that time, except that three smaller spots accompanied the larger one, a; and all of these, up to the 8th, that is, of July, were never once out of sight.
3. On the 8th those three very small ones just mentioned merged again into one; spot a, moreover, had also changed a great deal in size and brightness.
4. On July 9 all the smaller spots had dwindled away into faculae, except that larger one, a, which remained quite plainly visible right up to its setting. At the same time, moreover, a new spot, b, was then detected above the ecliptic towards the north, tiny though it was, near the eastern horizon [horizontem ortivum], among shining faculae. [Margin: Spots kindled into faculae.]
5. On the 10th the faculae b turned out somewhat weaker; spot a, however, was noticed for the last time.
6. On the 12th a new spot, c, again entered the Sun; the following figure will show its course. On that same day, however, the northern spot b had decreased a great deal.
7. On the 13th we saw a certain tiny, weak spot, d, generated on the Sun near its western part, which had certainly never been seen on the Sun's

disc before. But after it had lasted for the space of two days, by the 14th it was already so thinned that it almost escaped sight; the faculae that surrounded it, however, were reasonably conspicuous. On the 15th nothing but a very bright facula d was seen. Likewise b had been reduced entirely to nothing.

8. Concerning this period of spots, you have above all to note that spot a travelled on the Sun for about 13 days; and moreover that it kept a most regular course: [Margin: The spot remained on the Sun for about 13 days.]

for its daily motion, at the same distance from the centre or from the periphery, always remained alike and equal to itself. Finally, the annual motion of this spot gradually approaches the ecliptic, its curvature increases, and the Arctic pole rises.

Animadversiones super IX. Macularum Solarium periodo.

Remarks on Period IX of the Sunspots.

1. On August 12 a new spot, c, again arose, without faculae, in southern latitude; and on the following days, namely the 13th and 14th, faculae of no ordinary kind accompanied this spot c.
2. On the 14th new, conspicuous faculae, e, emerged in the northern quarter too. Of these, on the following day a certain brilliant, oblong facula was seen, with other, weaker ones, surrounding six new, weak spots that had been produced from them. [Margin: From very bright faculae, after the lapse of some hours, various spots were generated.]
3. On the 16th little worth noting remained of the faculae seen the day before; the spots, however, had grown to a monstrous extent and number, and indeed in an astonishing manner. In their progress, moreover, they varied very greatly indeed in number, shape and appearance, likewise in blackness and density, and in size as well, as is clear from the accompanying figure. As for the southern spot c, it gradually grew until about the middle, and then likewise decreased, both in size and in brightness. [Margin: A remarkable change in the spots.]
4. On the 17th the northern spots e drew farther and farther apart from one another; and at that time we also found them much larger and denser indeed than on the day before.
5. On the 18th they had again changed their shapes and position. It should be noted here, moreover, that at this very time spots e and c formed a perfectly straight line with the centre of the Sun. [Margin: Two spots seen in the same straight line with the centre of the Sun.]
6. On the 21st the larger spot e was seen decreasing, among widely spreading shadows and faculae. The three smaller ones following it, however, were so weak that they could scarcely be made out. And here again one must observe that the faculae went before the spots, while the shadows only

followed them, which certainly happens rarely. [Margin: Faculae rarely precede spots.]

7. On the 22nd the faculae noticed the day before could by no means be seen again, on account, that is, of small clouds continually veiling the Sun. Meanwhile, however, two new spots, f and g, were observed, newly risen on the Sun and never detected before, and fairly dense and conspicuous at that; in size they were equal to the spots c. Spot f was decreasing at once on the 23rd, so that on the 24th it seemed to have gone off into faculae; on that same day, too, it vanished utterly before it had reached the horizon, and it completed only three days on the Sun. [Margin: A newly risen spot went off again into faculae.]
8. On the 23rd, of those newly born the day before, only one, f, still survived; the other, g, was again entirely extinguished, so that it left not even a faint trace of itself. Here, then, one may rightly ask why this dissipated spot, like the other, f, did not last as long on the Sun as spot c, although it had been observed the day before to be just as large, dense and thick in its matter, while c nevertheless lasted on and the other, g, was reduced entirely to nothing. This is truly a matter worthy of wonder! [Margin: Although spots are generated together, they are nevertheless not of the same duration.]
9. I should like you to consider, moreover, that the faculae e varied notably from day to day. Next, that the apparent course of spot c was of 12½ days, more or less, whereas the spots e spent only 10 days on the Sun's visible hemisphere. [Margin: A course of 12½ days.]
10. On the 25th nothing more at all was seen of spot e; only a weak facula remained, near the setting. On the 26th, however, a new, very faint and very weak facula again appeared near the rising, and it was still shining on the 27th and 28th as well. But on August 29, 30 and 31, and also on September 1, the Sun was examined and found entirely clear of every spot and facula; so that it was only on September 2 that we again saw a facula near the eastern horizon, whose whole course we have drawn in the following figure [Margin: No spots, nor faculae, detected on the Sun.]

Diagram. An engraved plate inside a plate-mark in the upper part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved beneath it. A large Roman numeral "IX." stands at the upper left, outside the disc, and a three-line caption at the head of the disc. Hatched patches (faculae), touched in colour on the scan, stand in the upper left, at the left limb, in a very large mass right of centre, in a chain along the upper right towards the limb, and below the diameter at the left and right. Spots lettered e, each with a day figure, run across the disc above the diameter from the left limb to the right limb; spots lettered c, each with a day figure, run below the diameter from the left limb towards the right; spots lettered f stand at the right, on and below the diameter.

A table of observations for August stands in the lower half of the disc. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "IX."
- Caption (head of the disc): "GEDANI. Anno æræ Christianæ, 1643. Curſus Macularum, à 12 Augusti, ad 24 eiusdem" — *Danzig. In the year of the Christian era 1643. The course of the spots from August 12 to the 24th of the same month.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Beneath the diameter, centre: "Ecliptica." — *Ecliptic.*
- Hatched patch in the upper left: e, with 15 below
- Large patch at the left limb, above the diameter: e with 14
- Adjoining patch: e with 15
- Across the disc above the diameter, left to right: e with 16; e with 17; e with 18; e with 19; e with 20
- Very large patch right of centre: e, with 21 below and a second 21 at the patch's lower right
- Upper right, near the limb: e with 24
- Upper right, below a hatched patch: e with 23 and a small raised mark after it [?]
- Hatched patch at the right: e; 23 m by a spot below the patch
- Close cluster near the right limb, above the diameter: e with 22; e with 23; e with 23; e with 24
- On the diameter at the right, by a small patch: f
- Below the diameter, left to right: c with 12; c with 13; c with 14; c with 15; c with 16; c with 17; c with 18; c with 19; c with 20
- Cluster below the diameter at the right: f with 22; f with 23; f with 23; 24 below the small patch on the diameter; c with 21; c with 22; c with 23; c at the right limb with a figure set on its side [?]
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. QQ."
- Lower right: "Aut. Sculpsit." — *The author engraved it.*

August.

Day (D.)	Hour (Hor.)	l.		Ang.	
12	6	38	m.	34°	46′
13	7	31	m.	34	8
14	7	46	m.	35	34
15	7	56	m.	35	50
16	7	30	m.	34	40
17	7	26	m.	34	27
18	7	14	m.	34	4

Day (D.)	Hour (Hor.)	1.		Ang.	
19	7	21	m.	34°	5′
20	7	46	m.	34	44
21	6	51	m.	33	19
22	4	36	m.	75	0
23	7	18	m.	33	30
23	4	15	m.	76	0
24	7	36	m.	33	58

Diagram. An engraved plate inside a plate-mark in the upper part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved beneath it. A large Roman numeral "X." stands at the upper left, outside the disc, and a three-line caption at the head of the disc, with a table of observations for September beneath it. A row of single spots lettered c, each with a day figure, runs across the upper half of the disc from a hatched patch at the upper left towards the right limb. Hatched patches (faculae, touched in colour on the scan) lettered a, each with a day figure, lie along the diameter from the left limb to the right limb. In the lower half, spots lettered e, each with a day figure, run from the left limb towards the right, some in and beside a hatched patch at the lower left; three small dots lettered d stand above them in the middle, and two hatched patches lettered b stand near the right limb. A second table for September stands in the lower part of the disc. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "X."
- Caption (head of the disc): "GEDANI. Anno æræ Chriſtianæ, 1643. Curſus Macularum, à 2 Septembris, ad 26 eiſdem." — *Danzig. In the year of the Christian era 1643. The course of the spots from September 2 to the 26th of the same month.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Beneath the diameter, centre: "Ecliptica." — *Ecliptic.*
- Upper half, left to right: c with 10 (in a hatched patch); c with 11; c with 12; c with 13; c with 14; c with 15; c with 16; c with 17; c with 18
- Along the diameter, left to right: a with 2; a with 3; a with 4; a with 5; a with 7; a with 10; a with 11; a with 12; a with 13
- Lower half, left to right: e with 14; e with 15; e with 16; e with 17; e with 18; e with 19; e with 20; e with 21; e with 22
- Middle of the lower half, above the e-spots: d with 12; d with 13; d with 14
- Near the right limb, below the diameter: b with 3; b with 4
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. RR."
- Lower right: "Aut. Sculps." — *The author engraved it.*

September (upper table).

Day (D.)	Hour (Hor.)	l.		Ang.	
2	4	10	u. [?]	78°	19′
3	7	58	m.	34	16
4	8	18	m.	35	32
5	8	23	m.	35	45
7	9	16	m.	41	13
10	8	9	m.	34	54

Day (D.)	Hour (Hor.)	l.		Ang.	
11	2	10	u. [?]	89°	5′
12	1	38	u. [?]	84	17
13	12	41	u. [?]	74	29
14	9	16	m.	40	23
15	8	13	m.	35	15
16	7	57	m.	34	12

September (lower table).

Day (D.)	Hour (Hor.)	l.		Ang.	
17	10	20	m.	49°	23
18	9	36	m.	43	23
19	3	51	u. [?]	81	49
20	9	35	m.	43	29
21	9	24	m.	41	55
22	7	44	m.	33	41

Animadversiones super X. Macularum Solarium Periodo.

Remarks on Period X of the Sunspots.

1. On September 2 a new facula, a, sprang up near the rising; but apart from it nothing at all was noticed. On the 3rd, however, two quite tiny spots, b, emerged near the western horizon, surrounded by a very faint shadow; by the 4th they had left scarcely any trace behind them. [Margin: Spots arisen near the setting.]
2. On the 5th two newly born spots were observed among the faculae and shadows a; on the day before, scarcely one of them, very weak, could be made out. But on the 7th the faculae a again surrounded only one spot. [Margin: Shadow, the seed of spots.]
3. On September 6, 8 and 9 the clearness of the sky was not favourable.
4. On the 10th there appeared not only twin spots again, among broader faculae, but also a new spot, c, of no ordinary kind, with faculae shining fairly brightly, above the ecliptic and towards the north. I am fully

convinced that this spot entered the Sun on the 8th, when the sky was cloudy.

5. On September 11 the spots a had been dispersed entirely; the faculae, however, lasted until the 14th, on which day they left the Sun together. Here, moreover, it should above all be well noted that these faculae crossed the whole of the Sun's disc with a very regular motion, which otherwise rarely happens. For they usually either vanish around the middle or at least withdraw from sight. But from these observations it becomes quite plain that those faculae a lingered on the Sun for 13 days, more or less. Moreover, that the Arctic pole as it were culminated, and that the faculae described their motion at the autumnal equinox [ad æquilibrium autumnale], since at their rising and at their setting they were equally distant from the ecliptic, is abundantly clear from the accompanying diagram. [Margin: Faculae too sometimes complete their whole course on the Sun's visible hemisphere.] [Margin: The faculae's stay on the Sun was of about 13 days.]
6. Spot c kept its strength up to the middle: around the centre it appeared oblong and furnished with two nuclei; afterwards, however, it gradually thinned again, so that after September 18 it was no longer noticed; and hence it is certain that it stayed on the Sun for only about 10 days. Its motion, moreover, was again inclined with respect to the ecliptic: for here the Arctic pole began to descend from the zenith point towards the rising. [Margin: The Arctic pole descends.]
7. On the 12th, again, a new tiny spot, d — yet more than sufficiently conspicuous — was generated almost in the middle of the Sun's disc, and it appeared below the ecliptic, towards the south; on the 15th it vanished utterly. Of this spot I can affirm this above all, and with complete truth: that it neither entered the Sun nor left it, but was born, as it were, in the Sun's bosom, and died there again. [Margin: Spot d was born in the bosom of the Sun, and expired in the same place.]
8. On the 14th a new spot, e, came forth at the rising; we have decided to sketch its whole course, growth and decline in the following figure.

Animadversiones super XI. Macularum Solarium periodo.

Remarks on Period XI of the Sunspots.

1. Spot e, which came into our view on the 14th, was divided into several in the course of time; on the 19th these grew together into one again; thereafter, however, decreasing little by little from day to day, it degenerated into faculae, namely on September 23. On the 25th nothing but faculae, with a certain notable shadow, were detected. [Margin: A very notable shadow.]
2. On the 26th not only was a trace of those shadows still remaining, but a new spot, f, was also generated, almost in the middle of the Sun's disc;

on the 27th it was again entirely dissipated. [Margin: Spot f lived only a single day.]

3. As for the path of spot e, it seems to be quite parallel to the earlier one, c.
4. On the 28th the inclemency of the sky was adverse to observation. On September 29 and 30, however, as also on October 1, 2 and 3, nothing in the way of spots appeared on the Sun. Again, on October 4 nothing could be observed, because of the turbulence of the air. [Margin: The Sun free of spots.]
5. On the 5th and 6th I noticed a very splendid facula, g, above the ecliptic. On October 7 other faculae likewise, h, though weaker, were observed. But on the 8th, 9th and 10th we saw nothing at all on the Sun, because of the bad weather.
6. On October 11 two thin and tiny spots, i, were again born near the centre of the Sun; at the same time, too, a new facula, a, also shone out near the western horizon.
7. On the 12th, 13th and 14th the sky was cloudy.
8. On October 15 two spots, l, were again seen in the western region of the Sun, which on the 11th were no longer to be seen. As far as I can conjecture, however, these spots l took their origin from facula g.
9. On the 16th the spots just mentioned had grown in bulk, and had produced another, smaller, very weak spot.
10. On the 17th and 18th a turbulent sky was an obstacle to observation.

Diagram. An engraved plate inside a plate-mark in the upper part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved beneath it. A large Roman numeral "XI." stands at the upper left, outside the disc, and a three-line caption at the head of the disc, with a table of observations for September beneath it. A ring-shaped patch lettered g stands at the upper left; a small spot lettered f (marked with a bare "26", no month) and two letters l, each over a pair of spots and marked "Oct", lie above the diameter right of centre; large hatched patches lettered e stand in the upper right, and a hatched patch lettered k at the right limb on the diameter. Below the diameter, a hatched patch lettered h stands near the left limb, two small dots lettered i at the centre, and a row of spots lettered e, each with a day figure, runs from the left limb towards the right, ending in two large hatched patches near the right limb. A table for October stands in the lower part of the disc. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XI."
- Caption (head of the disc): "GEDANI. Anno æræ Christianæ, 1643. Curſus Macularum, à 14 Septemb. ad 11 Octob." — *Danzig. In the year of the Christian era 1643. The course of the spots, from September 14 to October 11.*
- A (left end of the diameter): A
- B (right end of the diameter): B

- Beneath the diameter, left of centre: "Ecliptica." — *Ecliptic.*
- Upper left, above the diameter: g with 5
- Above the diameter, right of centre: f with 26; l with "15 Oct"; l with "16 Oct"
- Below the diameter, near the left limb: h with 7
- Below the diameter, centre: i with 11
- Right limb, on the diameter: k with 11
- Lower half, left to right: e with 14; e with 15; e with 16; e with 17; e with 18; e with 19; e with 20; e with 21; e with 22; e with 23 (large patch); e with 25 (patch at the right limb)
- Upper right: e with 24 (large patch); e with 26 (at the limb)
- Table heads: "SEPTEMBRIS." — *September*; "OCTOBRIS." — *October*
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. SS."
- Lower right: "Aut. Sc." — *The author engraved it.*

September.

Day (D.)	Hour (Hor.)	l.		Ang.	
14	9	16	m.	40°	23
15	8	13	m.	35	15
16	7	57	m.	34	12
17	10	20	m.	49	23
18	9	30	m.	43	23
19	3	51	u. [?]	81	49
20	9	35	m.	43	29

Day (D.)	Hour (Hor.)	l.		Ang.	
21	9	24	m.	41°	55
22	7	44	m.	33	41
23	11	29	m.	61	0
24	10	4	m.	51	5
25	11	18	m.	59	5
26	8	4	m.	35	12

October.

Day (D.)	Hour (Hor.)	l.		Ang.	
5	9	26	m.	43°	49
7	10	40	m.	54	9
11	10	4	m.	49	30
15	8	57	m.	42	12
16	11	[?]7	m.	67	37

Diagram. An engraved plate inside a plate-mark in the upper part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter

marked A at the left and B at the right, with "Ecliptica." engraved beneath it. A large Roman numeral "XII." stands at the upper left, outside the disc, and a three-line caption at the head of the disc, with a table of observations for October beneath it. Above the diameter a row of spots lettered c and b, each with a day figure, runs from left of centre towards the right, ending in two hatched patches near the right limb (one touched in colour on the scan) lettered c. Below the diameter, five pairs of small spots lettered a, each with a day figure, run from the left towards the centre. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XII."
- Caption (head of the disc): "GEDANI. Anno æræ Christianæ, 1643. Curſus Macularum, à 19 Octob. ad 31 eiusdem." — *Danzig. In the year of the Christian era 1643. The course of the spots, from October 19 to the 31st of the same month.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Beneath the diameter, centre: "Ecliptica." — *Ecliptic.*
- Above the diameter, left to right: c with 25; c with 26; b with 21; b with 22; c (no figure beside it); b with 23; c with 29 (in a hatched patch); c with 30; c with 31
- Below the diameter, left to right: a with 19; a with 20; a with 21; a with 22; a with 23
- Table head: "OCTOBRIS." — *October*
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens," — *B. West.*
- Lower left, outside the disc: "fig. TT."
- Lower right: "Autor Sculps." — *The author engraved it.*

October.

Day (D.)	Hour (Hor.)	l.		Ang.	
19	10	20	m.	53°	16
20	8	58	m.	43	24
21	11	34	m.	64	51
22	12	50	u. [?]	77	5
23	10	24	m.	54	41
25	12	23	u. [?]	72	48

Day (D.)	Hour (Hor.)	l.		Ang.	
26	1	9	u. [?]	80°	5
28	10	55	m.	60	21
29	9	15	m.	47	24
30	10	23	m.	56	15
31	9	1	m.	46	21

Animadversiones super XII. Macularum Solarium periodo.

Remarks on Period XII of the Sunspots.

1. After the sky, then, had shone out clear on October 19, two spots, a, were seen afresh; on the 20th they had spread out more, and then on the twenty-first they were drawn apart into three offshoots. Afterwards, however, they gradually decreased in this way, and at last, on the 25th, they were entirely removed. [Margin: Inconstant spots.]
2. On the 21st, again, two spots, b, came into being, newly born near the centre of the Sun; afterwards, on the 23rd, they were reduced to a single very weak one and a very thin shadow, and at last, on the 25th, they perished completely. Such spots, and very many others like them, furnish us with an infallible argument that spots are generated near the Sun and are destroyed again.
3. On that very day, namely the 25th, when spots a and b appeared nowhere, three other very beautiful, dense and highly conspicuous spots, c, were seen in one and the same straight line, in the eastern region, above the ecliptic; I had certainly not seen them at all the day before. But whether they were generated on the Sun, or carried themselves onto it, is doubtful.
4. On the 26th the three spots c seen the day before, equal in size, had indeed grown in bulk and in distance; the middle one, by contrast, had decreased much in density. Of them all, the preceding one [antecedens] was found the more intense.
5. On the 27th the sky was covered with clouds.
6. On the 28th we found the middle c entirely erased, while the remaining two were separated by a still greater interval. The former was denser, while the latter was very weak, so that on the 29th scarcely any indication of it remained; again, widely spreading shadows were detected at that time with the other c. [Margin: Spots, although they are of the same opacity, do not however persist equally long.]
7. On the 30th that shadow, diffuse the day before, had contracted greatly: for it seemed smaller than the spot itself.
8. On the 31st spot c, drawing after it as it were a retinue of faculae, was seen for the last time, but very much diminished in brightness and bulk. The motion of this spot c, as also of the remaining spots a, is found to be curvilinear — convex, that is, towards the ecliptic, but concave towards the zenith; and likewise the Arctic pole descends in the eastern quadrant. [Margin: The Arctic pole descends.]

Animadversiones super XIII. Macularum Solarium periodo.

Remarks on Period XIII of the Sunspots.

1. On November 5, 9 and 20, although the sky was quite clear, the Sun was nevertheless seen free of every spot.

2. At last a new spot, k, arose on the 10th in the middle of the Sun's disc (of which not even a trace had appeared the day before) and came forth; but because of the gloom of the following days it was not observed at all thereafter. [Margin: Different spots, born in the very visible hemisphere of the Sun, and dispersed there as well.]
3. On November 24, again, five fresh spots, d, e, g, were seen near the rising horizon, forming an almost straight line. Of these the more southern ones, g, were fairly weak, while the middle one of the three larger, e, was found the densest and most opaque of all.
4. On the 25th all those spots had grown more than enough; d and e, however, were more intense than the rest. Besides this, another new spot, f, with shadows clinging to it, was also noticed at the very centre of the Sun; of these nothing at all, certainly, had been seen the day before. These likewise are clear proof (as has already been said quite often) that not all spots enter the Sun, but that some are also generated there at a fixed time.
5. On the 26th nothing was observed; but on the 27th spots d and c were seen wonderfully increased in bulk, density and nuclei, and crowned with a splendid halo. From those four weaker spots g, moreover, seven had now been born. In addition, two slender spots, h, also presented themselves to be seen. [Margin: A remarkable spot surrounded by a halo.]
6. On the 28th nothing more was noticed of the spots h noted the day before, but the remaining d, e, g still seemed to be growing little by little. On the following days, because of the continual bad weather of the sky, nothing at all was observed until December 3. On that day only one of them, d, still survived, together with a certain very weak spot and a facula; all the rest had either already gone out or had entirely expired.
7. From the fragment of the path of spots d, e and g it can be seen clearly that their motion was at first to some extent curvilinear, and concave towards the south, but towards their exit entirely rectilinear — spot d in particular confirming this. Such a course, indeed, is found at no other time than this, and in the month of June.

Diagram. An engraved plate inside a plate-mark in the upper part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved above the diameter right of centre. A large Roman numeral "XIII." stands at the upper left, outside the disc, and a three-line caption at the head of the disc, with a table of observations for November and December beneath it. Along the diameter, from the left limb to right of centre, stand spots lettered d and e, several of them ringed with stippling (a halo), with day figures; an elongated spot lettered d stands at the upper right near the limb. Below the diameter, groups of small spots lettered g stand at the lower left and right of centre (the latter enclosed by an angled line, with spots lettered f above it), a spot lettered k with a slanting

line beside it and a scatter of small spots below it at the centre, two small dots lettered h at the right, and a ring-shaped outlined patch lettered g at the right limb. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XIII."
- Caption (head of the disc): "GEDANI. Anno æræ Christianæ, 1643. Curſus Macularum, à 24 Nov. ad 3 Dec." — *Danzig. In the year of the Christian era 1643. The course of the spots, from November 24 to December 3.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Above the diameter, right of centre: "Ecliptica." — *Ecliptic.*
- Left part of the disc: d (spot on the diameter near the left limb); 24 (below the diameter at the left); d (elongated spot above the diameter); 25 (just below the diameter beneath it); e (spot below the diameter); e (spot further down at the left, with the 24 to its left)
- Centre, on and above the diameter: d (haloed spot); 27; d (haloed spot); e (haloed spot on the diameter); 28; e (haloed spot on the diameter)
- Upper right, near the limb: d with 3
- Below the diameter, right of centre: f with 25; g with 28 (cluster of small spots inside an angled line)
- Below the diameter, right: h with 27
- Right limb, below the diameter: g with 3 (ring-shaped patch)
- Centre, below the diameter: k with 10; 27 (beneath a scatter of small spots, no letter beside it)
- Lower left: g with 25; g with 24
- Table heads: "NOVEMBRIS." — *November*; "DECEMBRIS." — *December*
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. VV."
- Lower right: "Autor Sculpsit." — *The author engraved it.*

November.

Day (D.)	Hour (Hor.)	l.		Ang.	
24	10	0	m.	61°	13′
25	10	36	m.	64	58
27	11	21	m.	74	5
28	9	53	m.	61	54

December.

Day (D.)	Hour (Hor.)	l.		Ang.	
3	10	25	m.	67	49

Diagram. An engraved plate inside a plate-mark in the upper part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter

marked A at the left and B at the right, with "Ecliptica." engraved below the diameter at the left. A large Roman numeral "XIV." stands at the upper left, outside the disc, and a three-line caption at the head of the disc, with a table of observations for December and January beneath it. Two groups of small spots lettered a stand above the diameter at the upper left. Below the diameter, spots lettered c and b, each with a day figure, run from right of centre towards the right limb, where three spots lettered c stand in a row, the last two over a patch drawn in outline and touched in colour on the scan. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XIV."
- Caption (head of the disc): "GEDANI. Anno æræ Christianæ, 1643. Curſus Macularum, à 25 Dec. ad 25 Ian. An. 1644." — *Danzig. In the year of the Christian era 1643. The course of the spots, from December 25 to January 25 in the year 1644.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Below the diameter, left: "Ecliptica." — *Ecliptic.*
- Upper left, above the diameter: a with "24 Ian." (*January 24*); a with 25
- Below the diameter, right of centre: c with 25; b with "22 Ian." (*January 22*); c with 26
- At the diameter, right: b with 23
- Near the right limb, below the diameter: c with 29; c with 30; c with 31
- Table heads: "DECEMBRIS." — *December*; "IANVARII." — *January*
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. WW."
- Lower right: "Aut. Sculps." — *The author engraved it.*

December.

Day (D.)	Hour (Ho.)	l.		Ang.	
25	11	3[5 or 6] [?]	m.	88°	1′
26	10	0	m.	75	4
29	9	55	m.	75	44
30	11	26	m.	88	52
31	9	53	m.	76	19

January.

Day (D.)	Hour (Ho.)	l.		Ang.	
22	9	43	m̃.	83	53
23	9	20	m.	81	27
24	10	0	m.	86	41
25	10	21	m.	89	16

Animadversiones super XIV. Macularum Solarium Periodo.

Remarks on Period XIV of the Sunspots.

1. The restlessness of the air prevented us from being able to observe this remarkable, large and intense spot c, which you see sketched in figure WW, before December 25. It kept its form and shape constantly right up to its exit, except that near its setting it seemed a little more oblong; this, however, comes from the smaller angle of vision. [Margin: A very constant spot.]
2. In the year 1644, on January 1, 11 and 13, the Sun appeared entirely bare of every spot. On the 22nd, however, two spots b again emerged, but weak ones; of these the lower almost escaped sight on the following day. [Margin: Spots not at all stable.]
3. On the 24th the two spots b observed the day before had completely disappeared, so that nothing whatever remained; on the other hand, three others, never seen before, took their place in the eastern quadrant, generated for the first time that night; two of these were also observed on the following day.
4. The track of spot b was again curvilinear, concave towards the south and convex towards the north, as you have it marked in the diagram. [Margin: A curvilinear course.]

Animadversiones super XV. Macularum Solarium periodo.

Remarks on Period XV of the Sunspots.

1. On February 16, as I was again setting about observations, two spots appeared. The oblong one, b, was still clinging to the horizon, so that it was only just coming into view; but it was certain that the other, a, had already lasted some days. [Margin: A spot seen at the very horizon.]
2. On the 17th, b, seen the day before with its fairly notable shadow, had been transformed into two spots; a, however, kept almost the same appearance until the 20th.
3. On the 18th spot b, growing, drew along with it two new spots recently generated. At the same time new northern spots, e and d, remarkable for their density, also met us, although they had nowhere yet been seen on the previous day. From this it becomes plain that these spots were first condensed in the visible hemisphere of the Sun. [Margin: A wonderful change of the spots.]
4. On the 19th the sky was not favourable. But on the 20th b had grown remarkably,

and it seemed darker, because of two nuclei packed very densely together. Likewise d, distinguished by a single splendid nucleus, had been changed not a little in its size and in the intensity of its colour. The two spots e, however, had passed over into a very faint shadow and four spots. Further, I found c divided

into three, and a no less so, though with this difference: these last were set apart from one another by a large interval.

5. On the 21st, of the three spots a observed the day before, only one still remained, and that one very faint. Next, all three of those spots — the companions, that is, of b — had vanished completely and utterly into nothing, except that the spot b already mentioned still displayed exactly the same size and splendour. Spot d was found not diminished at all, but partly weaker. Spots of this kind, both large and highly observable, such as b, d and e were, one may certainly very rarely observe together on the Sun's disc; so I congratulated myself very greatly on having seen them on this day. [Margin: Many spots, and those by no means insignificant, observed together on the Sun's disc.]
6. On February 22 the sky was cloudy on every side.
7. But on the 23rd spots d and b changed not only their position but also their form and size, as can be seen; e, however, passed entirely into shadows.
8. On the 26th we were given the last opportunity of observing spots d and b as they approached the setting horizon; at that time, however, they were still found very dense and conspicuous on account of their nuclei.
9. On March 4 and 5 no spot at all was seen on the Sun; but on the 24th of the same month we again noticed three, by no means ordinary ones, near the western limb (these, however, have been gladly left out of the present figure XV, to avoid confusion).
10. You will note here that spot b crossed the ecliptic twice on this path; that the course of these spots was still concave towards the south; and likewise that its pole almost culminated. Hence the chords, as never fails to happen in equilibrium, stand almost equidistant from the ecliptic. [Margin: No inclination of the chords to the ecliptic.]

Diagram. An engraved plate inside a plate-mark across the middle of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved above the diameter right of centre and a short stroke from it down to the line. A large Roman numeral "XV." stands at the upper left, outside the disc, and a three-line caption at the head of the disc. An upper row of spot groups lettered e and d, each with a day figure, runs above the diameter from the left limb to the right limb, with a small spot lettered f among them at the left. Along the diameter, spots lettered b (above or on the line) alternate with spots lettered c and a (on or below it), each with a day figure; one spot a stands inside an angled line that opens to the left. Three small spots lettered g stand at the lower right inside the limb. A table of observations for February stands in the lower half of the disc. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XV."

- Caption (head of the disc): "GEDANI. Anno æræ Christianæ, 1644. Cur[[f/c]]us Macularum, à 16 Febr. ad 26 eiusdem." — *Danzig. In the year of the Christian era 1644. The course of the spots, from February 16 to the 26th of the same month.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Above the diameter, right of centre: "Ecliptica." — *Ecliptic.*
- Upper row, left to right: e and d with 18; f with "17 Mart." — *March 17*; e and d with 20; e and d with 21; e and d with 23; e and d with 26
- On and about the diameter, left to right: b with 16 (just below the diameter at the left limb); b with 17; c (at the diameter, no figure beside it); b with 18; [?] with 16 (below the diameter; the letter is c or a); c with 20; b with 20; a with 17; b with 21; a with 18; a with 20 (inside the angled line); b with 23; a with 21; b with 26
- Lower right, inside the limb: g with "17 Mart." — *March 17*
- Table head: "FEBRVARII" — *February*
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. XX."
- Lower right: "Aut. Sc." — *The author engraved it.*

February.

Day (D.)	Hour (Hor.)	/.		Ang.	
16	10	5	m.	93	1′
17	9	37	m.	89	52
18	8	17	m.	81	31
20	9	26	m.	88	46
21	9	39	m.	90	27
23	7	30	m.	79	50
26	10	41	m.	98	43

Diagram. An engraved plate inside a plate-mark across the upper and middle part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved above the diameter left of centre. A large Roman numeral "XVI." stands at the upper left, outside the disc, and a three-line caption at the head of the disc. One spot group lettered b, with its day figure, stands above the diameter right of centre. Below the diameter a row of spots lettered a runs from the left limb to the right limb, each with a day figure; the last two are large stippled groups. A table of observations for March and April stands in the lower half of the disc. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XVI."
- Caption (head of the disc): "GEDANI. Anno æræ Christianæ, 1644. Cur[[f/c]]us Macularum, à 25 Mart. ad 4 Aprilis." — *Danzig. In the year of the Christian era 1644. The course of the spots, from March 25 to April 4.*

- A (left end of the diameter): A
- B (right end of the diameter): B
- Above the diameter, left of centre: "Ecliptica." — *Ecliptic.*
- Above the diameter, right of centre: b with 28
- Below the diameter, left to right: a with 25; a with 26; a with 28; a with 29; a with 30; a with 1; a with 2; a figure 3 [?] standing alone just below the diameter towards the right; a with 3 (large stippled group); a with 4 (large stippled group)
- Table heads: "MARTII." — *March*; "APRILIS." — *April*
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. YY."
- Lower right: "Aut. Sc." — *The author engraved it.*

March.

Day (D.)	Hour (Hor)	/.		Ang.	
25	10	11	m.	94	53
26	9	0	m.	86	1
28	9	45	m.	90	58
29	7	31	m.	79	14
30	8	15	m.	81	33

April.

Day (D.)	Hour (Hor)	/.		Ang.	
1	11	32	m.	107	4[6 or 5] [?]
2	8	23	m.	81	46
3	10	1	m.	91	57
4	7	49	m.	79	18

Animadversiones super XVI. Macularum Solarium periodo.

Remarks on Period XVI of the Sunspots.

1. On March 25, at 7^h 30^m, a very bright facula a shone out near the eastern horizon. At 10^h 11^m it appeared again, somewhat diminished, as it were, both in size and in brightness; in its middle, on the other hand, a certain very small spot was seen, which had arisen within the space of two or three hours (and this should be well noted). [Margin: From a facula, within the space of three hours, a spot generated.]
2. On the 26th, from the facula of the day before and that single faint spot, five others were seen, no less extremely faint than extremely small, with no faculae at all attached to them.
3. On the 28th spots a grew considerably; at the same time two new spots b, very fluid and weak, newly generated around the centre of the Sun, also appeared. Of these certainly nothing whatever had been detected

the day before, although the sky was clear on every side; nor did they stay on the Sun longer than one day, since on the following day they had again been reduced entirely to nothing.

4. On the 29th, as also right up to their exit, they gradually decreased.
5. On April 3 we saw only a single, very faint spot, crowded about with faculae and shadows (which, however, for the most part went ahead of the spot). On the 4th, however, it was noticed on the Sun for the last time. Hence it is certain that this spot a did not reach the setting horizon, but expired entirely in the visible hemisphere of the Sun.
6. The southern pole of the transsolar path of this spot rose more and more towards the rising; the other, opposite pole descended towards the setting. [Margin: The southern pole rises.]

Animadversiones super XVII. Macularum Solarium Periodo.

Remarks on Period XVII of the Sunspots.

1. On April 3, before spot a of the preceding figure had completely left the Sun, another new and very dense spot, c, again made its entrance near the rising horizon, with faculae and shadows by no means ordinary.
2. On the 4th spot c stood out more than plainly among those gleaming faculae; afterwards it gradually grew in bulk up to about the centre of the Sun, but then decreased again.
3. On the 13th and 14th that same spot seemed considerably diminished. Moreover, the faculae which had deserted the spot on the second day after its rising accompanied it again on the second day before its departure — though with this difference, which I noticed: at the setting the faculae and shadows appeared somewhat paler. [Margin: When a spot is surrounded by faculae and shadows near its rising, this has generally happened near its setting as well.]
4. This spot, moreover, stayed on the Sun about 13 days, if you consider its true rising and setting accurately. Its path, as is quite clearly evident from the diagram, is still found to be convex towards the north and concave towards the south, except that it differs from the earlier courses of the spots in this alone: in the west it tends more and more downwards, but in the east upwards. For this reason, too, the lower pole inclines more and more towards the rising. [Margin: A course of 13 days.] From all of this, however, it becomes extremely plain that the motion of the spots is entirely regular and at all times most constant. And although these spots by no means last for ever, its motion is nevertheless uniform, so that in the same, similar months the same curvature of the motions and the same inclination of the chords to the ecliptic is always observed. [Margin: The motion of the spots is most constant.]

But lest the Peripatetics persuade themselves that we are deceiving them with empty show, we ask them not to be reluctant to read through the observations

of the most celebrated Christoph Scheiner, drawn with the greatest diligence, certainly, from the very face of the heavens and made both at Rome and elsewhere, as well as those made by others well practised in this business. I do not doubt, indeed, that they will at last acknowledge the wonderful constancy of the motions of the spots and the very great similarity of all the years, and will perceive both the risings and the settings of these spots, and their generations and corruptions — truly admirable — which also very often occur in the very centre of the Sun. But if anyone should still doubt our good faith in presenting these observations even a little (which, however, we scarcely expect), we promise to show him the autographs themselves as well, which we keep in reserve against every eventuality. For the rest, we can solemnly affirm that in drawing our observations and engraving them in copper we applied all the care we could, so as not to present anything, even in the smallest matter, at variance with the autographs themselves. For this reason too we publicly declare that we transferred each and every one of them to the copper plates with our own hand — not for display, but for the sake of good faith.

Diagram. An engraved plate inside a plate-mark across the upper and middle part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved above the diameter at the centre. A large Roman numeral "XVII." stands at the upper left, outside the disc, and a three-line caption at the head of the disc. Below the diameter a single row of ten spots runs from the left limb to the right limb, each lettered c above and carrying its day figure below; the first two (3, 4) and last two (13, 14) are large coloured, stippled groups, the rest small dark spots. A cluster of two or three small unlabelled dots stands lower down towards the right. A table of observations for April stands in the upper half of the disc, under the caption. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XV.II."[27]
- Caption (head of the disc): "GEDANI. Anno æræ Christianæ, 1644. Curſus Macularum, à 3 April. ad 14 eiusd." — *Danzig. In the year of the Christian era 1644. The course of the spots, from April 3 to the 14th of the same month.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Above the diameter, centre: "Ecliptica." — *Ecliptic.*
- Below the diameter, left to right: c with 3 (large stippled group); c with 4 (large stippled group); c with 5; c with 8; c with 9; c with 10; c with 11; c with 12; c with 13 (large stippled group); c with 14 (large stippled group)
- Table head: "APRILIS." — *April*
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. ZZ."

[27]as engraved, with a point between V and II; the plate numeral XVII

• Lower right: "Aut. Sculps." — *The author engraved it.*

April.

Day (D.)	Hour (Hor.)	/.		Ang. °	′
3	10	1	m.	91	57
4	7	49	m.	79	18
5	11	14	m.	103	52
8	7	15	m.	77	24
9	4	12	u. [?]	33	41
10	4	10	u. [?]	34	7
11	10	28	m.	94	55
12	8	21	m.	79	46
13	8	18	m.	79	19
14	7	40	m.	77	2

Diagram. An engraved plate inside a plate-mark across the upper and middle part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved above the diameter at the centre. A large Roman numeral "XVIII." stands at the upper left, outside the disc, and a three-line caption at the head of the disc. Above the diameter, just right of the left limb, a small cluster of dots on and over the diameter is marked 11 and g, with a short slanting stroke; right of centre a row of small spots lettered f (pairs of dashes, then a single dot) carries day figures. Below the diameter a double row of spots runs from the left limb to the right limb: an upper series lettered d, two of them with stippled halos, and a lower series lettered e, each pair or spot with its day figure; two slanting engraved strokes stand among the groups for the 10th and 11th. A figure 18 stands alone beside a grey stippled smudge between the groups for the 13th and 14th. At the right limb a large coloured, stippled group holds two spots lettered d with the figures 17 and 18. A table of observations for April stands in the lower half of the disc. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XVIII."
- Caption (head of the disc): "GEDANI. Anno æræ Chriſtianæ, 1644. Cu[[r/e]][[f/c]]us Macularum, ab 8 April. ad 18 eiusdem." — *Danzig. In the year of the Christian era 1644. The course of the spots, from April 8 to the 18th of the same month.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Above the diameter, centre: "Ecliptica." — *Ecliptic.*
- Above the diameter, towards the left: 11 with g
- Above the diameter, right of centre, left to right: f with 11; f with 13; f with 14; f with 15
- Below the diameter, left to right: d and e with 8; d and e with 9; d and e with 10; d and e with 11; d and e with 12; d and e with 13; 18 alone (beside

a grey smudge); d and e with 14; d and e with 15; d with 17 and d with 18 (in the large stippled group at the right limb)

- Table head: "APRILIS." — *April*
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. AAA."
- Lower right: "Autor Sculps." — *The author engraved it.*

April.

Day (D.)	Hour (Hor.)	/.		Ang. °	′
8	7	15	m.	77	24
9	4	12	u. [?]	33	41
10	4	10	u. [?]	34	7
11	10	23	m.	94	6
12	8	21	m.	72	46
13	8	18	m.	79	19
14	7	40	m.	77	2
15	8	7	m.	78	7
17	7	18	m.	75	34
18	7	7	m.	75	2

Animadversiones super XVIII. Macularum Solarium periodo.

Remarks on Period XVIII of the Sunspots.

1. On April 6 and 7 the inclemency of the sky stood in the way of my observing.
2. On the 8th, however, two new spots, d and e, appeared. Of these the upper, d, being the denser, was also surrounded by a nimbus or halo.
3. On the 9th e, the lower and weaker spot seen the day before, had spread into three; on the 10th, however, into four.
4. On April 11 all the spots had changed remarkably: whereas on the evening of the 10th we had seen only six, now fourteen were seen. For from spot d two new ones had been produced; likewise, below the ecliptic, five smaller ones, g; and also, above the ecliptic, two rather elongated ones, f. Besides these, a huge host of faculae and shadows was detected, both around the rising and around the setting (we did not wish, however, to enter them all, each and every one, in this figure AAA, to avoid confusion, but have deferred them to the following one) — so much so that we have hardly ever seen the Sun so suffused with spots, faculae and shadows, and almost overwhelmed by them. [Margin: The Sun crowded with very many spots, faculae and shadows.]
5. On the 12th, 13th, 14th and 15th spot d had grown a little; the four lower ones, e, however, had merged into one; the remaining spots, g, had increased not in number, indeed, but in bulk — as is plain from the following figure BBB, for which we have reserved them. Spots f, on the

other hand, diminished day by day, so that on the 15th they had passed into a single, very faint one.

6. On the 17th spots d and e were surrounded by faculae and shadows of various kinds.
7. On the 18th the faculae appeared brighter, but the spots somewhat smaller. Moreover, not far from the Sun's centre, in the western quadrant, some trace of a certain new spot appeared quite clearly, which was not seen further, either on the preceding day or on the following one.
8. The curvature of these paths is, as it were, decreasing: for it proceeds a little more straight than in the preceding figures. As for the stay of spots d and e, it lasted about 13 days. [Margin: The curvature of the path decreases.] [Margin: The course lasted thirteen days.]

Animadversiones super XIX Macularum Solarium periodo.

Remarks on Period XIX of the Sunspots.

1. Spots g, with an escort of faculae and shadows, entered the Sun on the 11th; on the 12th, however, they were entirely stripped of all escort.
2. On the 12th, 13th and 14th these spots grew not only in size but also in number and in distance; afterwards, however, they were seen to decrease — yet not as regards their brightness or density. [Margin: The spots increase, and move apart from one another.]
3. On the 18th only three still remained; the rest had either coalesced, or vanished entirely, or — what is more credible — had passed into very bright faculae, which, however, for lack of space, we did not wish to set down here.
4. On the 19th the previous day's spots still held almost the same position; on the 20th, however, they presented themselves on the same straight perpendicular, almost at the very periphery, but were so diminished that they could scarcely, if at all, be seen.
5. It should be noted for the present that these spots rose, as it were, in the northern part, above the ecliptic, but set again below the ecliptic, in the southern part of the Sun. [Margin: Worth noting.] Moreover, the curvature and inclination of these spots come altogether close to the curvature of the preceding ones; and this because they completed their course in the Sun at one and the same time.
6. On the 21st and 22nd we detected nothing whatever of spots, apart from some secondary ones spread over the whole of the Sun's disc. [Margin: Secondary spots.]
7. On the 24th, 25th, 26th and 27th the Sun, when surveyed, was still wholly free of every spot. On the 28th, however, a very dark spot was noticed near the rising.
8. On April 29, 30 and 31, as also on May 1, truly no spots or faculae came into view yet; and it deserves to be noted that within the space of those

eleven days, although the air was very clear, nothing notable met us in the Sun. [Margin: For a space of eleven days there was nothing in the Sun.]

Diagram. An engraved plate inside a plate-mark across the upper and middle part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved above the diameter right of centre. A large Roman numeral "XIX." stands at the upper left, outside the disc, and a three-line caption at the head of the disc, with a table of observations for April beneath it in the upper half of the disc. Along and just below the diameter a single row of spot groups runs from the left limb to the right limb, each lettered g above and carrying its day figure below: at the left limb a large coloured, stippled group (11), then a few small dots on the diameter (11), then clusters of small dark spots for 12, 13, 14 and 15; to the right of centre the groups for 17, 18, 19 and 20 descend towards the right limb, separated by short slanting strokes. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XIX."
- Caption (head of the disc): "GEDANI. Anno æræ Chriſtianæ 1644. Curſus Macularum, à 11 April. ad 20 eiusd." — *Danzig. In the year of the Christian era 1644. The course of the spots, from April 11 to the 20th of the same month.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Above the diameter, right of centre: "Ecliptica." — *Ecliptic.*
- Along and below the diameter, left to right: g with 11 (large stippled group); g with 11 (small dots); g with 12; g with 13; g with 14; g with 15; g with 17; g with 18; g with 19; g with 20
- Table head: "APRILIS." — *April*
- Lower part of the disc: "A Oriens." — *A East.*; "B Occidens." — *B West.*
- Lower left, outside the disc: "fig. BBB."
- Lower right: "Aut. Sc." — *The author engraved it.*

April.

Day (D.)	Hour (Hor.)	/.		Ang. °	′
11	10	23	m.	94	6
12	8	21	m.	79	46
13	8	18	m.	79	19
14	7	40	m.	77	2
15	8	7	m.	78	7
17	7	18	m.	75	34
18	7	7	m.	75	2
19	7	40	m.	75	45
20	8	24	m.	77	48

Diagram. An engraved plate inside a plate-mark across the upper and middle part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved above the diameter left of centre. A large Roman numeral "XX." stands at the upper left, outside the disc, and a three-line caption at the head of the disc. Two series of spots cross the disc. Above the diameter an upper series, lettered a, b and c, runs from the left limb to the right limb: at the left limb two coloured, stippled groups (3 and 4) with an outlined empty loop between them (7), then clusters of small spots for 6 and 7, a single spot with stippling for 8, and groups for 10, 11, 12 and 13, the last two close to the diameter by B; a wavy engraved line runs from the group for 11 towards the group for 12. Below the diameter a lower series, lettered d and e alternately, runs from the left limb (4) through small spots for 6, 7 and 8; from 10 onward each d is a large dark spot ringed with a dotted halo, with a small e beside it, descending towards the right limb through 11, 12, 13, 14, 15 and 16. A table of observations for May stands in the lower half of the disc. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XX."
- Caption (head of the disc): "GEDANI. Anno æræ Chriſtianæ 1644. Curſus Macularum à 3 Maii ad 16 eiusdem." — *Danzig. In the year of the Christian era 1644. The course of the spots, from May 3 to the 16th of the same month.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Above the diameter, left of centre: "Ecliptica." — *Ecliptic.*
- Upper series, letters left to right: a, a, b, c, a, b, c, a, b, c, a, b, c, a, a, a, a
- Upper series, day figures left to right: 3, 7, 4, 6, 7, 8, 10, 11, 12, 13
- Lower series, letters left to right: e, d, e, d, e, d, e, d, e, d, e, d, e, d, e, d, e, d, e, d
- Lower series, day figures left to right: 4, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16
- Table head: "MAII." — *May*
- Lower part of the disc: "A Oriens." — *A East.*; "B Occidens." — *B West.*
- Lower left, outside the disc: "fig. CCC."
- Lower right: "Autor Sculpsit" — *The author engraved it.*

May.

Day (D.)	Hour (Ho.)	/.		Ang. °	′
3	7	21	m.	70	47
4	6	55	m.	70	5
6	9	25	m.	77	31
7	8	16	m.	71	17
8	7	23	m.	69	0
10	8	26	m.	70	38
11	8	49	m.	71	55
12	9	55	m.	78	49

Day (D.)	Hour (Ho.)	/.		Ang. °	′
13	7	45	m.	67	44
14	7	54	m.	67	2[6 or 5] [?]
15	7	53	m.	66	57
16	6	46	m.	65	40

Animadversiones super XX: Macularum Solarium periodo.

Remarks on Period XX of the Sunspots.

1. Now at last, on the 3rd of May, in the morning, a new facula a revealed itself near the rising horizon, towards the north. In the afternoon it showed almost the same appearance, except that some matter of spots was also noticed.
2. On the 4th, five spots had been born from the faculae a seen the day before; on the preceding day they had scarcely given any trace of themselves. Besides these, however, two further spots, d and e — somewhat oblong, very black and very dense — were seen, which had just entered the Sun's disc towards the south. [Margin: From faculae, very dense spots came forth.] From these it is indeed plain to see that within by far the shortest interval of time — namely 13 or 14 hours — a remarkable generation and corruption of spots can certainly take place.
3. On the 5th the Sun did not shine at all; on the 6th, however, all the spots, especially the upper ones, which had arisen from faculae, had grown wonderfully.
4. On the 7th they had increased more and more, both in size and in their nuclei; and between spots b and a we noted a very faint shadow. Likewise we also saw a new, very bright facula at the rising, towards the north. [Margin: Spots varying from day to day.]
5. On May 8 they had all changed their form or shape again.
6. On the 9th the clearness of the sky by no means favoured observations. On the 10th, however, one could see with one's own eyes an altogether great metamorphosis of the spots, as much in size as in shape. For d in particular was not only found much larger and crowned with a most splendid halo, but it also showed a very dense, very black nucleus in its very middle, and also two small spots newly produced from the upper shadow. [Margin: A quite remarkable metamorphosis of the spots.] I scarcely remember having observed, over a long span of time, a larger and more remarkable spot than this one, namely d. [Margin: A very notable spot.]
7. On May 11, 12 and 13 the southern spot d remained steadily in its state, so that, together with the rest of its attendants, it always presented the same form, brightness and density. Spots a, by contrast, appeared much more compressed on the 13th, especially since at that very time they were at the very horizon; on the other hand they drew widely spreading faculae

and shadows along with them. Of these, on the following day, none survived (except some very faint ones).

8. On the 14th and 15th no spot at all appeared except that notable spot d, which, however, surrounded by faculae and shadows, gradually grew slender.
9. On the 16th this spot appeared oblong; although it was very close to the horizon, it was nonetheless very dense and most conspicuous
10. Note above all that this spot d grew day by day in the eastern quadrant and was variable, but in the western quadrant was most constant as to shape, size and density, so that, growing, it entered and left the Sun. [Margin: To be noted.] From this I was able to gather almost for certain that this very spot would, beyond all doubt, return, since this could well happen on account of the density of its matter and its size and vastness. [Margin: From which it could be conjectured that spot d would return.] But whether it returned at the proper time or not, the following observations will testify. Meanwhile, my reader, I would also like you to take note here that spot d, at 10^h on the same day, was fixed right on the horizon, as it also was at two in the afternoon, yet in such a way that it almost escaped sight. [Margin: A spot seen on the very horizon.] It is therefore certain that the spot just mentioned spent 8^h and more clinging to the horizon, but, if you work the calculation correctly, at least 12 days and 20^h in running across the whole visible hemisphere of the Sun. [Margin: The spot spent 8^h and more clinging to the horizon.] Moreover, its course in the eastern quadrant was still curvilinear, whereas in the western quadrant it formed an altogether straight line.
11. As regards the path of the other spot, a, we noticed that it was inclined to the ecliptic in almost the same way. But its motion in the eastern quadrant was certainly much quicker than that of spot d, as the figure itself attests. For in the first three days it covered about as much space in the Sun as the other, d, did in about 4 days — which well deserves to be noted. [Margin: The course of the northern spots was much quicker than that of the southern.] Hence it also stayed in the Sun by no means as long as that other, larger spot d, since, if you consider its whole course, it lingered on the Sun's disc scarcely 12 days.

Animadversiones super XXI. Macularum Solarium periodo.

Remarks on Period XXI of the Sunspots.

1. On May 14 the Sun was free of spots.
2. On the 15th we detected nothing whatever on the Sun's disc apart from a facula. On the 16th, however, several unusual spots, a and b, had already been produced from the previous day's facula. [Margin: A remarkable generation and increase of spots.]

3. The unsettled state of the air prevented me from observing those earlier spots before May 22. By that time, at last, they had not only grown in bulk, but in particular the leading spot b was very notable for its density, its nucleus and the remarkable halo by which it was girt; and likewise it showed almost the same appearance as that larger spot d in the preceding figure.
4. On the 23rd spot b was seen with almost the same size and shape, while the other, intermediate spots a were found very sparse; meanwhile, however, they changed their position wonderfully from day to day.
5. On the 24th the spots a just mentioned were seen still sparser, and b too had decreased somewhat.
6. On the 25th and 26th the following, smaller spots were so attenuated that they almost escaped sight.
7. On the 27th they had already vanished entirely, and in its place very many faculae mixed with shadows had been substituted. [Margin: Some spots degenerated into faculae.]
8. On the 28th spot b appeared very slender near the setting, as usually happens because of the more oblique angle of vision, and likewise surrounded by shadows and faculae. But at 4^{h} in the afternoon it was seen on the very limb of the Moon; from this it is certain that it spent about 12^{h} on the western horizon. [Margin: A spot noticed on the very western horizon.]

Its duration, moreover, from the time of its generation, was about 13 days. And its course, as far as one may gather, was almost rectilinear — such a course as has certainly been observed at all times around the beginning of June. [Margin: A course almost rectilinear.] Lastly, a new spot f, near the rising horizon towards the north, surrounded by faculae and shadows, again presented itself to our eyes; you will have its period in the following figure.

Diagram. An engraved plate inside a plate-mark across the upper and middle part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved below the diameter left of centre. A large Roman numeral "XXI." stands at the upper left, outside the disc, and a three-line caption at the head of the disc. A single series of spots, each group lettered a and b above, runs from near the left limb to the right limb just above and along the diameter: a small cluster for 16 near the left limb; then, from 22 onward, b is a large dark spot ringed with a dotted halo and a is a row of small stippled spots beside it, the groups for 22, 23, 24, 25 and 26 descending slightly below the diameter and separated by short vertical strokes across it; at the right limb a large coloured, hatched patch of faculae surrounds the spots b for 27 and 28. A table of observations for May stands in the lower half of the disc. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XXI."

- Caption (head of the disc): "GEDANI. Anno æræ Christianæ 1644. Curſus Macularum, à 16 Maii, ad 28 eiusdem." — *Danzig. In the year of the Christian era 1644. The course of the spots, from May 16 to the 28th of the same month.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Below the diameter, left of centre: "Ecliptica." — *Ecliptic.*
- Letters of the series, left to right: a, b, a, b, a, b, a, b, a, b, a, b, b, b
- Day figures, left to right: 16, 22, 23, 24, 25, 26, 27, 28
- Table head: "MAII." — *May*
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. DDD."
- Lower right: "Aut. Sculps." — *The author engraved it.*

May.

Day (D.)	Hour (Hor.)	/.		Ang. °	′
16	8	33	m.	6	29
22	7	13	m.	63	10
23	7	2	m.	62	40
24	7	24	m.	62	21
25	8	36	m.	64	35
26	6	30	m.	61	40
27	6	19	m.	61	18
28	6	14	m.	61	3

Diagram. An engraved plate inside a plate-mark across the upper and middle part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved above the diameter right of centre. A large Roman numeral "XXII." stands at the upper left, outside the disc, and a three-line caption at the head of the disc, with a table of observations for May below it; a table for June stands in the lower part of the disc. At the left limb a large coloured, hatched patch of faculae carries several spots and labels. Two series of spots run from it towards the right: an upper series, lettered f, of small spots and dots above the diameter, ending on the diameter; and a lower series, lettered e, of dark spots ringed with dotted haloes, below the diameter and descending slightly to the right, the largest at the middle. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XXII."
- Caption (head of the disc): "GEDANI. Anno æræ Christianæ 1644. Curcus Macularum, à 28 Maii, ad 7 Iunii."[28] — *Danzig. In the year of the Christian era 1644. The course of the spots, from May 28 to June 7.*
- A (left end of the diameter): A

[28] «Curcus» so engraved, for «Curſus».

- B (right end of the diameter): B
- Above the diameter, right of centre: "Ecliptica." — *Ecliptic.*
- In the patch of faculae at the left limb, top to bottom: f (over a spot near the limb), 28 (on the limb), f (over a spot at the right edge of the patch), 30; below the patch 6 and [?]; nearer the limb [?], with 5 below it; e (on the limb by A), e (over a spot on the diameter just inside the limb), 31 (on the limb below the diameter); [?] below the lower part of the patch.
- Upper series (f), left to right, with day figures: f 31, f 1, f 3, f 4, f 5 (the last on the diameter, with a point and a short dash above it)
- Lower series (e), left to right, with day figures: e 3, e 4, e 5, e 6, e 7
- Table heads: "MAII." — *May*; "IVNII." — *June*
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. EEE."
- Lower right: "Aut. Sculps." — *The author engraved it.*

May.

Day (D.)	Hour (Hor.)	/.		Ang. °	′
28	6	17	m.	61	0
30	6	38	m.	60	16
31	6	35	m.	59	52

June.

Day (D.)	Hour (Hor.)	/.		Ang. °	′
1	6	51	m.	59	27
3	6	39	m.	58	31
4	6	26	m.	58	10
5	6	37	m.	57	38
6	7	20	m.	56	56
7	7	42	m.	56	46

Animadversiones super XXII. Macularum Solarium periodo.

Remarks on Period XXII of the Sunspots.

1. Spot f, newly risen on the 28th, was followed by a still larger retinue of faculae and shadows, namely on May 30. The body of this spot itself was found fairly dense, it is true, and conspicuous, yet wholly without nuclei. [Margin: A spot without a nucleus.]
2. From May 31 to June 1 spot f thinned day by day, until on the 3rd and 4th it was divided into four; but on the 5th, when they were seen for the last time, they again merged [caluerunt; recte: coaluerunt] into a single, very thin spot. [Margin: A spot which had just spread out into several merged into one again.] At the same time, at the rising, almost directly beneath the ecliptic itself, a new spot e, accompanied by faculae,

came into view once more. That it is to be counted among the returning spots, and is that very large and outstanding spot d shown in image XX, I gather most clearly from the following reasons. First, because it entered the Sun a second time — after 27 days had passed, that is — and indeed at about the same part of the periphery. [Margin: A spot entered the visible hemisphere of the Sun a second time.] Second, because, moreover, it appeared in exactly the same form — rounded, that is — and likewise surrounded by a halo, just as in its earlier course, namely in image XX.

3. This returning spot e grew, both in bulk and in density, up to the 5th of May, but afterwards gradually decreased again. Note, however, if you please, that in this case it did not acquire its former size.
4. On the 6th and 7th not even a trace was noticed of the very thin spot seen on the 5th, so that it had been entirely extinguished before it reached the western horizon; e, however, still remained quite conspicuous. But on the following days, because of the gloomy face of the sky, we were by no means able to record the further progress and change of this spot e. And this spot was, on these grounds, quite especially notable: first, because, endowed with a very conspicuous form, it crossed the Sun twice — the first time, namely, growing, but the second time decreasing. [Margin: To be noted.] Second, because its path in both courses was almost rectilinear, and it was itself girt at all times with a remarkable halo — something that is certainly very rarely seen.

Animadversiones super XXIII. Macularum Solarium periodo.

Remarks on Period XXIII of the Sunspots.

1. On June 13, when the Sun had again shone clearly upon us, we caught sight of spot a. We are thoroughly persuaded that it is no less a returning spot than the preceding one, e. [Margin: A returning spot.] Indeed, from all the circumstances — from its position as much as from the time of its return — one may surely conjecture that it is, by name, spot b, sketched in figure XXI and noticed around the setting on the 28th. This second time, however, it decreased day by day, so that on June 22 it was found on the Sun for the last time. Its course, moreover, as is clearly evident from those three observations, was now again partly curvilinear — concave, that is, towards the north. [Margin: A curvilinear course.]
2. On the 24th nothing was seen but weak faculae, at the rising as well as at the setting; these, however, were by no means put into this image, because of the narrowness of the paper.
3. On the 25th, 26th and 27th the sky was continuously cloudy; but on the 28th the clearness of the sky favoured us again, at which time we saw a newly produced spot c, accompanied by very bright faculae. Just as it increased in bulk up to the 4th, so it then gradually diminished; and it was noticed on the Sun for the last time on July 9, so that it lingered there

about 13 days. [Margin: The spot travelled beneath the Sun for about 13 days.]

4. On June 30, fresh spots d and b came forth once more. Although an immense tract of faculae stood beside them at the same time, we by no means thought it worth the effort to sketch it this time. I would, however, have you know full well, my reader, that spot b was very striking on account of its nucleus and the density of its matter, and likewise that it grew until July 5. On that day a certain smaller spot too, newly formed for the first time, clung to the larger one; but it was not our lot to notice it for more than one day. The larger, b, by contrast, did decrease from day to day, but nonetheless showed itself quite clearly at all times. Spot d, however, did not reach the western horizon, but was completely dispersed on the Sun's disc, namely on July 8
5. On July 3, three new, very thin spots e, quite slender, were born near about the middle of the Sun. Afterwards, in the course of time, they varied exceedingly, both in form and in number, as is more than plain from the accompanying diagram. In the western quadrant, however, they gradually diminished again in number, bulk and density, so that around their exit only a single one could be seen — crowned, though, with faculae of the most exceeding brilliance.

Diagram. An engraved plate inside a plate-mark across the upper and middle part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved just below the diameter right of centre. A large Roman numeral "XXIII." stands at the upper left, outside the disc, and a three-line caption at the head of the disc, with a table of observations for June below it; a table for July stands in the lower part of the disc. Coloured, hatched patches of faculae stand at the upper left, lower left, upper right, right limb and lower right. Spot a runs on a dotted track from the upper left down to the diameter at the middle and on below it. Above the diameter a series of small clusters lettered e runs from left of centre to the right limb. Below the diameter three dotted tracks, lettered b, c and d from top to bottom, descend slightly from the left limb to the right limb; the larger spots of b are ringed with dotted haloes. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XXIII."
- Caption (head of the disc): "GEDANI Anno æræ Chriſtianæ, 1644. Curſus Macularum, à 13 Iunii, ad 10 Iulii." — *Danzig. In the year of the Christian era 1644. The course of the spots, from June 13 to July 10.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Below the diameter, right of centre: "Ecliptica." — *Ecliptic.*
- Patch of faculae, upper left: c, 29
- Track of a, left to right: a 13 (above the diameter), a 17 (on the diameter), a 22 (below it)

- Series e, above the diameter, left to right: e 3, e 4, e 5, e 7, e 8, e 9, e 10 (the last three at and in the patch of faculae at the right limb, e 10 by B)
- Track b, left to right: b 30 (at the left limb), b 2, b 3, b 4, b 5, b 7, b 8, b 9, b 10
- Track c, left to right: c 28 (at the left limb), c 29, c 30, c 2, c 3, c 4, c 5, c 7 (in the patch of faculae at the lower right), c 8, c 9 (on the limb)
- Track d, left to right: d 30 (on the left limb), d 2, d 3, d 4, d 5, d 7, d 8
- Patch of faculae, upper right: b (over a spot above the patch), 10
- Patch of faculae, lower left: c, 28
- Patch of faculae, lower right: b, 9, c (by a spot at the limb)
- Table heads: "IVNII." — *June*; "IVLII." — *July*
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. FFF."
- Lower right: "Aut. Sculp[[f/s]]." — *The author engraved it.*

June.

Day (D.)	Hour (Hor.)	/.		Ang. °	′
13	8	17	m.	55	9
17	6	6	m.	53	9
22	6	18	m.	51	3
24	6	45	m.	50	25
28	6	25	m.	48	0
29	6	56	m.	47	20
30	7	48	m.	47	23

July.

Day (D.)	Hour (Hor.)	/.		Ang. [°]	′
2	6	46	m.	46	15
3	7	38	m.	45	48
4	7	13	m.	45	16
5	7	46	m.	46	17
7	6	43	m.	44	23
8	6	39	m.	44	23
9	7	10	m.	43	45
10	6	55	m.	43	25

Diagram. An engraved plate inside a plate-mark across the upper and middle part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved just above the diameter at the middle. A large Roman numeral "XXIV" stands at the upper left, outside the disc, and a three-line caption at the head of the disc, with a table of observations for July below it. A single series of small groups of dark spots, each lettered f, runs below the diameter from the middle of the disc to the right limb, the last two standing in a coloured,

hatched patch of faculae near the limb. A second patch of faculae, with one dark spot in it and no letter, stands above the diameter near the right limb. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XXIV"
- Caption (head of the disc): "GEDANI. Anno æræ Christianæ, 1644. Curſus Macularum, à 7 ad 12 Iulii." — *Danzig. In the year of the Christian era 1644. The course of the spots, from July 7 to 12.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Above the diameter, at the middle: "Ecliptica." — *Ecliptic.*
- Series f, below the diameter, left to right: f 7, f 8, f 9, f 10, f 11, f 12 (the last two in the patch of faculae near the right limb)
- Table head: "IVLII." — *July*
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. GGG."
- Lower right: "Aut. Sc." — *The author engraved it.*

July.

Day (D.)	Hour (Hor.)	/.		Ang. °	′
7	6	43	m.	44	23
8	6	39	m.	44	23
9	7	10	m.	43	4[?]
10	6	55	m.	43	2[5 or 6] [?]
11	6	42	m.	43	2
12	7	53	m.	43	11

Animadversiones super XXIV Macularum Solarium periodo.

Remarks on Period XXIV of the Sunspots.

1. On July 7, near the centre of the Sun and towards the south, several thin spots f were generated. [Margin: Several spots arose in the middle of the Sun.] This is established with certainty by the fact that on the day before nothing at all was seen on the Sun, however carefully I scanned it. All these spots indeed grew little by little from day to day, as the figure attests. Beyond this, however, nothing worth noting occurred in this period of the spots, except that their course was inclined and curved in quite the same manner as that of the preceding ones.
2. From July 14 to 21 nothing whatever of spots or faculae was noticed on the Sun. On the 22nd, however, a facula sat on the rising horizon.
3. On the 23rd and 24th, apart from faculae and secondary shadows, we found nothing — believe me — on the visible hemisphere of the Sun. [Margin: Secondary spots.] On the 25th, however, only a single facula shone out.

Animadversiones super XXV. Macularum Solarium Periodo.

Remarks on Period XXV of the Sunspots.

1. Now at last, on July 26, two spots were rising, namely g and h. The upper and smaller, h, diminished day by day up to the middle of its path, where it was reduced entirely to nothing, so that not any trace of it remained. [Margin: A spot near the centre of the Sun disappeared entirely.] The other, lower one, g, grew up to the middle; afterwards, however, decreasing gradually, it ceased to be on the Sun together with exceedingly bright faculae.
2. On August 3, conspicuous faculae went before spot g — something that certainly happens very rarely, for these usually follow the spots. At that very time a new facula i was seen near the rising, which on the following day turned into two exceedingly thin spots.
3. The course of spot g was still curvilinear, and indeed concave towards the north, because its north pole was staying in the western quadrant.
4. The travel time of spot g, if it is weighed properly, did not exceed 12 days by much. [Margin: Its apparent course lasted 12 days, more or less.]
5. On August 5 and 6 continuous rain denied us the sight of the Sun. On the 7th, however, we were again free to observe; but not even the smallest thing, either spot or facula, met us. Likewise on the 8th, 9th and 10th nothing whatever of spots appeared. On the 11th and 12th, again, the air was turbid. [Margin: For how long a time the Sun was entirely free of spots.]
6. On the 14th, 15th, 16th, 18th, 19th and 20th the Sun still showed a face clean in every part. But what happened over the following 5 days we were by no means permitted to observe, because of the inclemency of the sky.
7. On the 26th, spots were indeed noticed by us once more; but because of small clouds covering the Sun we were allowed to note nothing at all.

Animadversiones super XXVI. Macularum Solarium periodo.

Remarks on Period XXVI of the Sunspots.

1. On August 27 we detected a single spot a, almost in the middle of the Sun's disc. Whether it had entered the Sun, or was first born in its bosom, I truly cannot affirm with certainty, since the preceding days had been cloudy. For the same reason, too, it fell to us to see this spot a no more than twice.
2. On September 2 two new spots b came into view again. As they moved towards the setting, they changed from day to day both in form and in number, so that near their exit only two small ones presented themselves, surrounded by shadows and very bright faculae.
3. On September 10 and 11 widely spread faculae c were seen towards the rising, below the ecliptic; on the 12th they were again completely

dispersed, and before the 18th no trace of spots or faculae appeared. After this, up to the 25th, the Sun was again observed to be entirely clean.

Diagram. An engraved plate inside a plate-mark across the upper and middle part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved just below the diameter at the middle. A large Roman numeral "XXV." stands at the upper left, outside the disc, and a three-line caption at the head of the disc, with a table of observations for July below it; a table for August stands in the lower part of the disc. Above the diameter, a series of small spots lettered h runs from a coloured, hatched patch of faculae at the left limb towards the middle, at 26 to 30; beside the first two stand small unlettered marks with the figures 3 and 4. Below the diameter, a series of larger spots lettered g runs from the left limb (26, and 27 inside a patch of faculae) across the middle to the right of centre (2, 3, 4), with one further g at 3 a little below the series. A second g 26 stands in a patch of faculae at the lower left; two more patches of faculae stand near the right limb, one with the figure 4 below it. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XXV."
- Caption (head of the disc): "GEDANI. Anno æræ Chriſtianæ, 1644. Curſus Macularum, à 26 Iulii, ad 4 Auguſt." — *Danzig. In the year of the Christian era 1644. The course of the spots, from July 26 to August 4.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Below the diameter, at the middle: "Ecliptica." — *Ecliptic.*
- Patch of faculae above the diameter at the left limb: h 26 (a spot at its upper edge); a small figure 1 inside the patch; 3 below the patch
- Beside h 27: a small figure 1, between two dots, with 4 below
- Series h, above the diameter, left to right: h 26, h 27, h 28, h 29, h 30
- Series g, below the diameter, left to right: g 26 (on the left limb), g 27 (in a patch of faculae), g 28, g 29, g 30, g 2, g 3, g 4
- Below and between g 2 and g 3: g 3
- Patch of faculae right of g 4, near the right limb: 4 (no letter)
- Patch of faculae at the lower left: g 26
- Patch of faculae at the lower right: no label seen
- Table heads: "IVLII." — *July*; "AVGVSTI." — *August*
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. HHH."
- Lower right: "Autor Sculp[[ſ/c]]it:" — *The author engraved it.*

July.

Day (D.)	Hour (Ho.)	/.		Ang. °	′
26	7	18	m.	38	22
27	7	13	m.	38	6

Day (D.)	Hour (Ho.)	/.		Ang. °	′
28	6	40	m.	37	49
29	7	10	m.	37	33
30	7	7	m.	37	13

August.

Day (D.)	Hour (Hor.)	/.		Ang. °	′
2	7	36	m.	37	15
3	6	51	m.	36	30
4	6	48	m.	36	16

Diagram. An engraved plate inside a plate-mark across the upper and middle part of the leaf, laid out like the plates before it: the Sun's disc cut by a horizontal diameter marked A at the left and B at the right, with "Ecliptica." engraved just above the diameter at the middle. A large Roman numeral "XXVI." stands at the upper left, outside the disc, and a three-line caption at the head of the disc, with tables of observations for August and September below it; a table for October stands in the lower part of the disc. Above the diameter, a dotted track runs from a pair of spots lettered b at "2 Sept" on the left, through "Ecliptica.", to clusters of spots lettered b at 8 and 9 and to two clusters at 10 and 11 inside a coloured, hatched patch of faculae at the right limb; a single small spot under a tall letter carries "8 Oct" left of the middle. Below the diameter, a second dotted track joins spots lettered d at "30 Sept", "2 Oct", 4 and 5; two patches of faculae lettered c stand at the left limb, a large unlettered patch of faculae at the right, and spots lettered a ("27 Aug", "28 Aug") and e ("2 Oct", "4 Oct") stand in the lower middle. The figure number is at the lower left, outside the disc, and the engraver's line at the lower right.

- Upper left, outside the disc: "XXVI."
- Caption (head of the disc): "GEDANI. Anno æræ Christianæ, 1644. Cuecus Macularum, à 27 August. ad 8 Oct."[29] — *Danzig. In the year of the Christian era 1644. The course of the spots, from August 27 to October 8.*
- A (left end of the diameter): A
- B (right end of the diameter): B
- Above the diameter, at the middle: "Ecliptica." — *Ecliptic.*
- Above the diameter, left: b, "2 Sept" (September 2)
- Above the diameter, left of the middle: f [?] (or long s), "8 Oct" (October 8)
- Series b, above the diameter, right of centre: b 8, b 9, b 10, b 11 (the last two in the patch of faculae at the right limb)
- Patches of faculae at the left limb, below the diameter: c with the label "[[6/b]]10" [?]; c with the label "11"

[29] «Cuecus» so engraved, for «Curſus».

- Series d, below the diameter, left to right: d "30 Sept" (September 30), d "2 Oct" (October 2), d 4, d 5
- Below the middle: a "27 Aug" (August 27), a "28 Aug" (August 28)
- Below and right of the middle: e "2 Oct" (October 2), e "4 Oct" (October 4)
- Large patch of faculae below the diameter at the right: no label seen
- Table heads: "AVGVSTI." — *August*; "SEPTEMBRIS." — *September*; "OCTOBRIS." — *October*
- Lower part of the disc: "A. Oriens." — *A. East.*; "B. Occidens." — *B. West.*
- Lower left, outside the disc: "fig. III."
- Lower right: "Aut. Sculps." — *The author engraved it.*

August.

Day (D.)	Hour (Hor.)	/.		Ang. °	′
27	7	26	m.	31	19
28	7	23	m.	33	9

September.

Day (D.)	Hour (Hor.)	/.		Ang. °	′
2	7	41	m.	33	31
8	7	39	m.	33	15
9	7	31	m.	32	50
10	7	49	m.	33	47
11	7	31	m.	32	50
30	8	33	m.	38	5

October.

Day (D.)	Hour (Hor.)	/.		Ang. °	′
2	11	49	m.	64	27
4	8	16	m.	37	4
[5 or 6] [?]	8	[5 or 6]5 [?]	m.	41	0
8	8	6	m.	36	45

4. On 30 September a remarkable spot d at last appeared, highly conspicuous for its three very dense nuclei. Yet it decreased in a wonderful way: by the 2nd, that is of October, only a small remnant of that large and very dense spot was left at that time, and a very thin one at that — as can be seen, as in a mirror, in the figure below. Besides this, toward the south, we also saw a very thin spot e, newly arisen, which on the following day died away again and was kindled into very bright faculae.
5. On the 6th nothing at all of spot d was to be seen.

[Margin: A spot lasting two days at most.]

6. On 8 October we again detected a very faint and small spot f, newly produced in the bosom of the Sun. Of this one I can affirm in particular that it did not carry itself onto the Sun's disc near the rising edge, and that on the very next day it was again reduced to nothing.
7. Up to 5 November nothing was noted or remarked, because the air was too turbulent. So too on the 14th, 25th, 28th, 29th and 30th, on 2 December, the 3rd, 4th, 5th, 6th, 11th, 16th and 21st, and likewise on 5 January in the year 1645, the 6th, 13th and 24th, the Sun appeared wholly cleansed of all spots. And it is truly remarkable that in so long a span of time nothing at all came forth. Whether anything emerged on the Sun on the intervening days, when the gloomy face of the sky did not allow us to observe at all, is certainly unknown to me; yet it matters greatly to know it. I would therefore earnestly beg all observers of celestial phenomena, if they directed watchful eyes at the Sun at that time, to inform us about these days. For if they too were unable to make out anything with their eyes on the intervening days mentioned above, then it will certainly be permissible to declare without hesitation that the Sun was seen for three entire months clean and pure, free of every spot and every facula. This deserves above all to be noted — the more so since, as far as I know, it has never yet been detected by anyone. With these, then, we shall close our observations of the spots too, since we have spoken of them at sufficient length, I think, in certain earlier chapters; and we shall turn to the contemplation of the Jovials, so that we may no less make plain to you, candid reader, everything that is properly to be noted there.

OBSERVATIONES QUÆDAM Circulatorum Jovis, quæ eorundem, cùm circumcurſitationes, tum mutationes, & ad ſe invicem, tum ad Jovem conſideratorum, accuratè exhibent; inſtitutæ, Anno Salutis 1642: 1643. 1644. GEDANI.

Some Observations of the Circulators of Jupiter, which accurately show both their revolutions and their changes, considered with respect both to one another and to Jupiter; made in the Years of Salvation 1642, 1643, 1644. At Danzig.

1. In the year from the birth of Christ 1642, on 13 August, at 11^{h} Gregorian style, I detected three satellites around Jupiter by means of a very precise telescope. The more easterly one, tending toward the north, was the largest of all; another, the smallest of the rest, formed a straight line with Jupiter and the more easterly one. Their configuration, among themselves as well as with respect to Jupiter, was as follows: a b, 14′; a c, 5′; and c d, 30″.
2. On 14 August, at 10^{h} 30^{m}, three little stars again appeared. The larger eastern one deviated slightly to the north from a straight line drawn through the others; the more westerly ones were of small magnitude.

They stood apart from one another, and from Jupiter, in this way: a b, 5′; b c, 6′; and a d, 11′.

3. At $11^h\ 15^m$ they had changed their position and place quite noticeably, and all were found larger and brighter. Their arrangement was as follows: a b, 7′; b c, 7′; and a d, 14′.
4. On 15 August, at $10^h\ 25^m$, we again saw only three little stars surrounding Jupiter: two equal in magnitude, in the west, and the third, the largest of the others, in the east — and indeed in this order and at these distances: a b, 3′; b c, 3′; a d, 11′.
5. On the same day, at $10^h\ 35^m$, we found the intervals between the same stars changed in this way: a b, 2′ 20″; b c, 2′ 20″; a d, 11′.

[Margin: The companions of Jupiter appear now larger, now also brighter.]

6. At 1^h after midnight, that is on 16 August, the more westerly ones had become much diminished, both in magnitude and in brightness, and had likewise changed their position not a little, as you see: a b, 2′; b c, 1′ 30″; and a d, 10′.

Diagram. Engraved plate, fig. KKK: *Observation of the Circumjovials*. Under the title "Circumiovialium" stand two columns of fourteen ruled boxes each, numbered 1–14 (left column, headed "Obcervatio") and 15–28 (right column, headed "Obcervatio."). Each box shows Jupiter as a circle lettered a, with its companions drawn as small stars, each lettered above. In boxes 1 and 15 the circle carries the sign of Jupiter (♃). The plate gives no dates or hours. Positions are given left to right as engraved:

- Box 1: d (star), c (a smaller star below and to the right of d, letter beneath it), a ♃, b (star far right).
- Box 2: d, a, b, c.
- Box 3: d, a, b, c.
- Box 4: d, a, b, c (b and c close to Jupiter).
- Box 5: d, a, b, c (b and c close to Jupiter).
- Box 6: d, a, b, c.
- Box 7: d, a, b, c.
- Box 8: d, a, b c (two stars set close together).
- Box 9: c, b, a; no star to the right.
- Box 10: d, a, b, c (c drawn larger).
- Box 11: e, d, a, b, c (c drawn larger).
- Box 12: e, d, a, b, c.
- Box 13: e, d (set high, just left of Jupiter), a, b c.
- Box 14: e, d (small, just left of Jupiter), a, b c.
- Box 15: e, d (set high), a ♃, b c (close together).
- Boxes 16–19: e, then d c b (three stars just left of Jupiter, c set high), a.
- Box 20: e, d c (close together, the second set high), b (touching Jupiter on the left), a.
- Box 21: e, c b (close together, one set high), a; a small mark touching the left edge of the circle is not drawn as a lettered star.

- Box 22: d, c, a, b.
- Box 23: d, c (drawn larger), a, b.
- Box 24: e, a, b, c, d (d set low).
- Box 25: e (labelled "fixa" beneath, a fixed star), d (set high), a, b c.
- Box 26: a star labelled "fixa" with e beneath it, d (set high), c b, a.
- Box 27: a star labelled "fixa" with e beneath it, d, e, a, b — the letter e is engraved twice in this box.
- Box 28: d, c b (close together), a.

Engraver's line, in box 14: "Aut Sculps." (engraved by the author). Plate mark: fig. KKK.

7. At 1^h 11^m after midnight, the ones moving to the right had so diminished that they could scarcely, if at all, be made out.
8. At 1^h 30^m those two small ones were drawing closer and closer to each other, so that b c were only 40″ apart; the other one, d, was about 9′ from Jupiter.
9. On 16 August, at 10^h 45^m, only two circumjovials were visible, toward the east; the others appeared nowhere. The one farther from Jupiter was the largest; it stood off from the other, smaller one, b, by three minutes, exactly as this one stood off from Jupiter. At 11^h 15^m, as far as could be observed, they had changed neither distance in the least.
10. On 17 August, at 10^h 45^m, we found the eastern little star d, the smallest of the rest, inclining toward the north this time; on the other hand, it stood farther from Jupiter, namely 9′. The western ones, b c, were separated from each other by only 4′ — that is, by the same interval as the nearer one from Jupiter.
11. On 18 August, at 10^h 25^m, we at last saw all four — something not granted until then — very splendid and very bright, to our very great delight. Of the western ones the outermost little star was the largest, and the nearer one the smallest. A straight line ran through all of them, as it did through the centre of Jupiter. Moreover, in their separation they kept this order and proportion: a b was 4′; b c, 2′ 30″; and no greater distance a d was found; d e, however, was 9′.
12. At 11^h 10^m on the same day the nearer eastern one had not changed its position at all, but the rest were receding more and more from Jupiter, as well as from one another. The distance of the eastern ones was found at that time to be 11′; that of b and Jupiter, 6′; and that of b and c, 3′. At 11^h 30^m all were of almost the same magnitude, except the one nearer to Jupiter, d: formerly the smallest of the rest, it was now seen as the largest.

[Margin: The Jovials too have their own latitudes.]

13. On 19 August, at 10^h 25^m, as I observed again, four stars appeared, but not all on one and the same straight line. For the nearest, d, standing 1′ 30″ from Jupiter, tended toward the north; the farther eastern one was the largest of the rest, and stood about 14′ from Jupiter;

but the western one, b, only 3′, and from the other one, c, 1′ 30″.

14. On the same day, at 10^h 45^m, the three nearer ones seemed considerably changed; more and more they were making their way toward Jupiter. d was 2′ from Jupiter, b 2′ 30″ from it, while c stood only a single minute from b.
15. At 11^h 15^m the more westerly ones, b c, were scarcely 50″ apart from each other, while d was gradually moving away from Jupiter, as the figure attests.

[Margin: All seen in the east.]

16. On 20 August, at 10^h 20^m, all four were shining in the east. The outermost of them was the largest; of the remaining three, smaller ones, the middle one was raised a little towards the north-east [Aquilam]. The nearer one, b, was found to be the smallest of all; it was separated from Jupiter — and the rest likewise from one another — by no more than one and a half minutes; e, however, was 12′ from d.
17. At 10^h 40^m the nearer ones had partly changed position, so that the upper one, c, was gradually tending toward d, and b toward Jupiter, as is clearly evident from the distances: a b, 1′; b c, 1′ 30″; c d, 1′.
18. At 10^h 55^m the outermost one, as far as we could judge, kept almost the same place; but the rest formed this arrangement: a b, 50″; b c, 1′ 30″; c d, 50″.
19. At 11^h 6^m the three nearer ones had decreased much in magnitude; b in particular almost escaped sight. c and b were carried with contrary motion. This can be clearly gathered from the fact that both c and d, and b and a, had become still closer in this observation: for the distance a b was found to be only 40″; b c, 1′ 30″; and c d likewise 40″.
20. At 11^h 30^m that smallest one, b, was making toward Jupiter with great speed, and was already, as it were, clinging to its limb. The two remaining ones, c and d, were preparing for a conjunction: they were apart by an interval of only 30 minutes, and b was apart from Jupiter by a still smaller space, namely 20″. Hence the distance c b extended to two full minutes.

[Margin: A conjunction worth noting.]

21. At 11^h 40^m that small one, b, was entirely covered by Jupiter, though at 10^h 20^m it had stood quite far from it;

and this spectacle, just as it was most delightful to see, was equally most worthy of observation.[30] The remaining two, c and b, were only 20″ apart, so that the one almost touched the other.

22. On 21 August, at 10^h 10^m, we found three little stars standing with Jupiter in a straight line along the course of the zodiac, as usually happens. The western one, the smallest, was 3′ distant from Jupiter; c, however, was 7′ from Jupiter and 5′ from the other one, d. At 10^h 35^m the arrangement of the stars differed almost not at all from the previous one.

[30] This sentence begins on PDF p. 738.

23. On 22 August, at $9^h\ 40^m$, those three circumjovials showed nearly the same face as on the day before, as is clearly evident from the order they kept: a b, 3′; a c, 8′; and c d, 4′.

On the 23rd and the following days we observed nothing whatever, because the sky was continuously cloudy.

24. On 29 August, at $10^h\ 57^m$, four stars were indeed again present around Jupiter, but two of them, namely c and d, were (as could be seen from the subsequent observations) among the fixed stars. b, the one nearer to Jupiter, almost escaped sight.

On 31 August, as also on 1 September, the weather was cloudy.

25. On 2 September, at $10^h\ 0^m$, we again found a fixed star in the east, standing almost in the same straight line with Jupiter and its attendants. Of the remaining three, the more easterly had a fairly notable northern latitude, while the western ones had none. The distance a b was 1′ 30″, as was b c, and a d was as great. At $10^h\ 48^m$ they had still not changed their order at all.
26. On 3 September, at $8^h\ 45^m$, all were seen in the east. We found that the outermost fixed star, e, had moved away from Jupiter by a still greater interval, namely 19′; for Jupiter was pursuing its retrograde course. Of the Jovials, d was turning aside toward the north; the intervals between all three were nearly equal, namely 2′. At $10^h\ 24^m$ they were still in the same arrangement, except that d had moved a little farther away from Jupiter.
27. On 4 September, at $9^h\ 50^m$, all four that appeared kept the same straight line; nevertheless the leftmost, e, turned out to be not one of the Jovials but one of the fixed stars;

this we established amply enough, both from its excessive distance from Jupiter and from the fact that it always kept the same position. The order of the rest was as follows: we estimated the distance a b at 1′; a c, 5′; c d, 3′; and a e about 30′.

28. On 6 September, at $10^h\ 40^m$, three appeared in the east, of almost the same magnitude. The more distant one, d, was 7′ away from c; c, however, was 1′ from b, and b 2′ from Jupiter.
29. On 7 September, at $9^h\ 52^m$, four were seen forming a straight line with the centre of Jupiter. The western one, b, almost escaped sight because of the smallness of its body. They held the following arrangement with respect to one another, as also to Jupiter: a b, 30″; b c, 2′ 30″; a d, 2′ 30″; d e, 6′.
30. On 8 September, at $8^h\ 43^m$, two again stood beside Jupiter on the east, and likewise two on the west; of these the more easterly inclined toward the south. Their order and distances can be correctly gathered both from the figure and from the numbers given here: a b, 4′ 30″; b c, 4′ 0″; a d, 1′ 30″; d e, 5′ 30″.

31. At 9^h 43^m the distances had changed in this way: a b, 4′; d c, 3′; a d, 2′; and d e, 5′.
32. On 9 September, at 8^h 33^m, we found only three, equal in magnitude, arranged precisely in the same straight line, and likewise the fixed star e, standing 26′ toward the north-west. The nearer of the two, b, was 2′ 30″ from Jupiter and in turn 3′ 30″ from c; d, however, was 3′ distant from Jupiter.
33. On 10 September, at 8^h 30^m, the position of the stars was as follows: b stood 1′ from Jupiter, while c stood 2′ 30″ off, and only 2′ from the other, eastern one, d.
34. On 11 September, at 8^h 50^m, besides that fixed star, 24′ distant from Jupiter, three were seen in this arrangement: b was 3′ 30″ from c and 2′ 30″ from Jupiter, and d was 4′ 30″ from it.
35. At 10^h 18^m, on the western side, we also observed a fourth, though a very small one, just emerging from the shadow of Jupiter; the other, following one, c, was turning aside toward the north.

Diagram. Engraved plate, fig. LLL, headed *Circumiovialium* ("Of the Circumjovials"), with *Obcervatio* ("Observation") over each of its two columns. The plate is divided by ruled lines into numbered boxes: 29–39 in the left column and 40–54 in the right. Each box draws one observation as a row of small stars beside a circle; the letters are engraved above the bodies, and in every box the circle carries the letter a. The sign of Jupiter (♃) is engraved inside the circle in boxes 29 and 40. Fixed stars are marked *fixa* ("fixed star"). The inscription "Aut. Sc." stands in the lower left corner of box 39, and "fig. LLL" at the lower right of the plate. Lettered bodies in each box, left to right:

- 29: e, d, a (♃), b, c
- 30: c, d, a, b, c
- 31: e, d, a, b, c
- 32: d, a, b, c; above right, a star marked *fixa.* with e
- 33: d, c, a, b
- 34: d, a, b, c; above right, a star marked *fixa* with e
- 35: e, a, b, c, d
- 36: e, a, b, c, d
- 37: e, d, a, b, e; an unlettered star stands below the number
- 38: e, d, a, b, c
- 39: d, a, b, c; above left, a star marked *fixa.* and a second star marked e
- 40: a (♃), b, c, d
- 41: a, b, c, d; at upper left, two unlettered stars marked *fixa.*; at far left, a star marked e above and *fixa.* below
- 42: a, b, c, d, e
- 43: a, b, c, d, e
- 44: a, b, e [or c?], d, e
- 45: a, b, c, d, e (with a short stroke after the e)
- 46: e, d, a, b, c

- 47: e, d, a, b, c
- 48: c, a, b
- 49: e, d, c, a, b
- 50: e, d, c, a, b
- 51: e, d, c, a, b
- 52: e, d, c, a, b
- 53: e, d, c, a, b
- 54: e, d, c, a

Blank page (the verso of the plate fig. LLL; the plate shows through in mirror image).

36. At 10^h 58^m, b, newly risen, was as far from Jupiter as from the other one, c — about 1′ — and was moving more and more toward the west, that is, toward the little star d. The eastern one, e, was 5′ distant from Jupiter.
37. On 12 September, at 8^h 29^m, Jupiter, moving retrograde, had come to conjunction with the following star in the first stream of the water. At that time it had two satellites on each side, all forming an entirely straight line, and they were nearly equal in magnitude. Here are the intervals between them: a b, 3′; d c, 4′; a d, 1′ 30″; d e, 3′.
38. At 9^h 56^m the order of the stars was this: a b, 3′ 30″; b c, 5′; a d, 1′ 30″; and d e, 5′.

On 13 September we noticed nothing whatever, because clouds intervened.

39. On 14 September, at 8^h 41^m, the conjunction of Jupiter and the star mentioned above was already past. Below that fixed star, with the help of an excellent spyglass, we noted yet another, unknown one, but much smaller. Around Jupiter only three companions were present (the fourth was perhaps still hiding in the shadow), in this configuration: the distance a b was 2′ 30″; b c, 9′; a d, 3′.
40. On 15 September, at 8^h 15^m, again only three were seen, on the west, of which the middle one was more southerly; and they stood at the following elongations from one another: a b, 2′ 30″; b e, likewise as many minutes; and c d, 4′.
41. On 16 September, at 8^h 5^m, three were again seen in the west, but holding an entirely different figure, as is clearly evident from their distances noted here: a b, 1′ 30″; b c, 4′; c d, 2′ 30″.
42. At 8^h 45^m on the same day, having examined the circumjovials carefully, we noticed no small change in them. For whereas in the earlier observation only three stood beside Jupiter, we now saw four quite distinctly; so it is certain that b, that nearer and very small star, had previously lain entirely hidden under the other one, c. Now newly seen, it stood no more than 20″ from c; the rest, as appears, kept nearly their former position.
43. At 9^h 30^m the nearer ones, b and c, were moving farther and farther apart, so that b, the smallest, was heading toward Jupiter at a hastening pace. In this observation we found their distance to be 30″.

44. At 10^h 5^m it had become so faint that it could barely be seen at all; it was no more than 20″ from Jupiter, but 50″ from the other one, c.
45. At 10^h 40^m that smallest one, b, was entirely hidden by Jupiter; the rest had changed their position very little. [Margin: A Jovial covered by Jupiter itself.]
46. On 17 September, at 8^h 43^m, all four were proceeding in a straight line. b, which was only 30″ from Jupiter, was the smallest of the rest. c, more westerly, standing 4′ from b, was quite conspicuous, as were the remaining eastern ones, which were 2′ apart from each other, while d was 2′ 30″ from Jupiter.
47. At 9^h 28^m b was only 15″ from Jupiter; b from c, 4′; d from Jupiter, 2′ 30″; and d from e, 2′. At 9^h 46^m that smallest one, b, was no longer to be seen — not so much because of the smallness of its body as because it was wholly veiled in darkness by Jupiter. [Margin: Eclipse of a Jovial.]
48. On 18 September, at 8^h 48^m, we observed only two stars, the brighter in the east, the other in the west; the former stood 5′ from Jupiter, the latter 2′ 30″.
49. On 19 September, at 8^h 24^m, all four showed the same magnitude. The middle one of the eastern ones rose a little toward the north; otherwise they were separated from one another by nearly equal intervals, namely 2′. But the western one was 4′ 30″ from Jupiter.
50. At 9^h 20^m the position of Jupiter's companions was not much different from the previous one, except that d e and a d had drawn a little closer together.
51. On 20 September, at 9^h 11^m, all of them, four in number, were very bright. The second from Jupiter, d, was turning aside toward the south; the rest described an exactly straight line with Jupiter. Considered both with respect to Jupiter and to one another, they kept this order: a b was at that time 1′ apart; a c, 1′ 30″; c d, 1′ 30″; and d e, 3′ 30″.
52. At 10^h 10^m we found b, the smallest, much nearer to Jupiter, so that it was only 30″ away.
53. At 10^h 25^m that western one, b, was already clinging closely to Jupiter's limb, for it was scarcely 20″ away from it. Of the rest we noted the intervals d c and c a as 2′, but e and d as 4′.
54. At 10^h 44^m that small western one, running into Jupiter's shadow, vanished completely, so that afterwards it could be found nowhere. [Margin: Jupiter covered a Jovial.]
55. On 21 September, at 8^h 25^m, of the three set in the same straight line, the western one, b, appeared the smallest; it was 1′ 30″ from Jupiter; c, however, 3′ 30″, and from the other, d, 6′ 30″. At that very time two fixed stars not yet seen up to that time came into view together toward the south-west; the upper of them almost escaped sight. [Margin: Fixed stars hitherto unknown.]

56. At 9^h 43^m that western star had already moved a single minute farther away from Jupiter.
57. On 22 September, at 8^h 15^m, three satellites surrounded Jupiter, keeping this order: b was 3′ from Jupiter, d 11′, but b was 3′ 30″ from c.
58. On 23 September, at 8^h 20^m, of the four satellites three were seen in the west; of these the nearer were very small, but the rest fairly large and very bright. e, the eastern one, heading for its farthest limit, was about 12′ from the king; the other, d, 7′; but the smaller ones, b and c, were separated by an equal interval both from each other and from Jupiter, namely 1′. The fixed stars seemed to be drawing a little closer to Jupiter.
59. At 9^h 4^m we saw that the two smaller ones, b and c, were much closer together, so that they were no more than 30″ apart.
60. At 9^h 17^m c, having acquired some northern latitude, was moving at a swift pace toward both the other star, b, and Jupiter.
61. At 9^h 30^m it is plainly found from the interval between b and c, namely 10″, that they had almost touched each other. [Margin: Two Jovials touch each other.]
62. At 9^h 41^m the one was grazing the other.
63. At 9^h 56^m these two, b and c, had come into conjunction itself, and together formed, as it were, altogether a single little star; [Margin: The one entirely covered the other.]

a most delightful sight indeed, such as it had never until then fallen to me to observe.

64. On 24 September, at 8^h 5^m, four little stars again accompanied Jupiter, in this order: b was 2′ 30″ from Jupiter; c, 2′; d, however, was 2′ 30″ from c, and 5′ 30″ from e.
65. At 9^h 2^m b was 1′ 50″ from Jupiter, while c was, as it were, stationary. d was 2′ distant from c, and 5′ from the outermost, e. At 9^h 34^m the western one had come still closer to Jupiter, so that it was only 1½′ away.
66. On 25 September, at about 10^h, because the sky was cloudy, we could observe only this single little star, toward the east, 5′ from Jupiter.
67. On 26 September, at 8^h 19^m, three companions were seen around Jupiter in the same straight line, and at these distances: d was 7½′ from Jupiter; c, 2½′; b, 5′. Besides these stars, 7 fixed stars also presented themselves to us at the same time, in exactly the order you see in the accompanying diagram.
68. On 27 September, at 8^h 9^m, we noticed two small ones, b and c, in the west, only a single minute apart, of which the more distant was turning aside toward the south. The eastern one, d, about 6′ from Jupiter, was the largest of all, as on the previous day.
69. At 9^h 37^m four were now shining: e had only now freed itself from Jupiter's shadow, and was so faint that it could barely be made out at all; its distance was noted as about 30″. b and c were seen twice as remote

as in the previous observation. The more southerly one seemed to be retrograde, against the succession of the signs; the other, b, direct, in the succession of the signs, toward Jupiter. [Margin: A Jovial coming from conjunction.]

70. On 28 September, at 7^h in the evening, the order of the Jovial stars, and of the fixed stars as well, was as follows: b stood 8′ from Jupiter, c 1′ 30″, d 3′ from c. The fixed star e, however, was nearly 20′, and f 30′.

71. At 8^h 43^m the smallest of the rest was hurrying more and more toward Jupiter; it was scarcely 40″ away from it.

Diagram. Engraved plate, fig. MMM: *Observations of the Circumjovials*, boxes 55–74. The plate is ruled into two columns of numbered boxes: 55–66 down the left column, 67–74 down the right. Each box shows Jupiter as a disc lettered a, with the box number engraved above the letter, and the companions as small stars lettered beside it; fixed stars appear in some boxes. The engraved title runs across the head (”Circumiovialium”), with ”Obcervatio” over each column. Signed at the foot left ”fig MMM.” and at the foot right ”Aut. Sculp.” (engraved by the author). Bodies are listed left to right as engraved.

- 55: d, c, a (disc marked with the sign of Jupiter, ♃), b; at lower right two stars labelled ”fixæ.” (fixed stars)
- 56: d, c, a, b
- 57: d, a, b, c; at lower right two stars labelled ”fixæ.” (fixed stars)
- 58: e, a, b, c, d; at lower right two unlettered stars
- 59: e, a, b and c close together, d
- 60: e, a, b and c close together, d
- 61: e, a, b and c close together, d
- 62: e, a, b and c touching, d
- 63: e, a, a single merged star with b above it and c below it, d
- 64: e, d, c, a, b
- 65: e, d, c, a, b
- 66: b, a
- 67: d, c, a (disc marked ♃), b; at upper right two unlettered stars; below, a star lettered e and labelled ”fixa.” (fixed star); at lower right a group of four stars, the large one lettered f, labelled ”fixæ.” (fixed stars)
- 68: d, a, b, c; at lower right a star lettered e, a large star lettered f, and two unlettered stars
- 69: d, e, a, b, c
- 70: d, c, a, b; at lower right a star lettered e, a large star and two smaller unlettered stars; a faint stroke above the large star is not read [?]
- 71: d, c, a, b
- 72: a, b, c, d; at lower right a star lettered e, a large star lettered f, and two unlettered stars
- 73: a, b, c, d
- 74: a, b, c, d

Blank page (the verso of the plate, which shows through in mirror image).

72. On 29 September, at $10^h\ 25^m$, three appeared in exactly the same straight line, of which the two more remote were very bright, but the third not so. b and c were separated by an equal distance, namely 2½′, from each other as well as from Jupiter; but d was 3½′ from c.
73. On 30 September, at $7^h\ 49^m$ in the evening, three were again seen in the same straight line, along the course of the zodiac; the nearest of all seemed the smallest. We found the distance d c to be 4′, b c 3′, and a b 2½′.
74. At $9^h\ 7^m$ the configuration of the Jovials was almost the same, except that b was noticed to be a little nearer.

On 1 October nothing could be observed, because clouds intervened.

75. On 2 October, at $7^h\ 27^m$, four were attending Jupiter. The eastern one, e, 1′ distant from the other, d, inclined toward the north; d, however, 2′ from Jupiter, formed an entirely straight line with the remaining western ones. The distance between b and Jupiter was 2½′, and that of c 11′. As for the fixed stars, they kept exactly the configuration drawn in the diagram, both with Jupiter and with his companions. F, the largest of three fixed stars, is elsewhere named the leading one of the two in the first stream of the water, of the sixth magnitude, in Aquarius; the rest were entirely new and hitherto unknown.
76. At $8^h\ 37^m$ the eastern one, e, was hurrying at a swift pace toward the east, so that at that time it was 2½′ from d; the rest still kept nearly the same distance among themselves.
77. On 8 October, at $7^h\ 50^m$, all were again found in the same position. b was 4′ distant from Jupiter; c, 7′; d, 2½′; e, however, 6½′ [?].
78. At $9^h\ 8^m$ we saw the eastern one, d, as the smallest of all. As for their position, all still kept almost the same, except that b had come a little closer to c.
79. On 4 October, at $9^h\ 25^m$, two in the west were seen so close that they almost touched each other, for they seemed to be no more than 15″ apart; they were separated from Jupiter by 2′, but the other, d, by 5′. [Margin: Two little stars very closely joined.] Day by day the fixed stars, toward Jupiter, more

and more were drawing near; the reason for this is that Jupiter was retrograde at that time.

On the 5th, 6th and 7th we could note nothing, because of the inclemency of the sky.

80. On 8 October, at $7^h\ 45^m$, three were seen. The more eastern was not indeed so large, but it was nevertheless conspicuous enough; it was about 12′ from Jupiter. The western one was found to be the largest, at a distance of 4′; c was 3′ away from Jupiter. The fixed stars, however, were 11′ toward the east.

On 9, 10 and 11 October the sky again was not favourable.

81. On 12 October, at $6^h\ 41^m$, three of the same size presented themselves in the east; the two nearest were separated by equal intervals from each other as well as from Jupiter, namely by a single minute; but d appeared 20″ more remote.

On 13 October, as also on the 14th, nothing could be observed, because clouds intervened.

82. On 15 October, at $7^h\ 45^m$, all those standing by Jupiter were amply conspicuous; nevertheless the middle one, b, 4′ distant toward the west, was the largest of all; the eastern one, d, 2½′ from Jupiter, was found to be the smallest.

On 16 and 17 October the air was very turbulent.

83. On 18 October, at $7^h\ 43^m$, two seemed fairly bright, but the third scarcely met the eye. b stood 2′ from Jupiter, c 11′, and d 7′.

84. At $8^h\ 3^m$ on the same day four were now appearing along the course of the ecliptic: the nearer one, b, had only then first emerged from Jupiter's rays, and was only 30″ distant.

On 19 October the weather was not at all suitable for observing.

85. On 20 October, at $9^h\ 41^m$, three small ones, arranged in this way, were seen toward the west. The first, b, was 1½′ from the Prince; c, 3½′; and d, 5′. The fixed stars, however, were about 30′.

86. On 21 October, at $7^h\ 48^m$, the little stars had changed their position, as is plain from the accompanying figure: b was 4½′ from Jupiter, c 8′, and d 1½′. Moreover, in this observation three new, unknown fixed stars were seen toward the north. [Margin: New fixed stars observed.]

Diagram. Engraved plate, fig. NNN: *Observations of the Circumjovials*, boxes 75–96. The plate is ruled into two columns of numbered boxes: 75–84 down the left column, 85–96 down the right. Each box shows Jupiter as a disc lettered a, with the box number engraved above the letter, and the companions as small stars lettered beside it; some boxes show further stars below or above the line of the companions. The engraved title runs across the head ("Circumiovialium"), with "Obcervatio" over each column. Signed at the foot left "fig NNN." and at the foot right "Aut. Sc." (engraved by the author). Bodies are listed left to right as engraved.

- 75: e, d, a (disc marked with the sign of Jupiter, ♃), b, c; below, a star labelled g, an unlettered star, a large star lettered f, and a lower unlettered star
- 76: e, d, a, b, c
- 77: e, d, a, b, c
- 78: e, d, a, b, c
- 79: d, a, then a pair of touching stars with b above and c below; below, a large star lettered e and two unlettered stars
- 80: d, c, a, b; below c, a large star lettered e and two unlettered stars
- 81: d, c (set higher), b, a
- 82: d, a, b, c

- 83: d, a, b, c
- 84: e, a, b, c, d
- 85: a (disc marked ♃), b, c, d; below, a large star lettered e and two unlettered stars
- 86: above, three unlettered stars, one labelled "fixæ" (fixed stars); then d, a, b, c
- 87: c, a, b
- 88: c, b, a
- 89: d, c, a, b
- 90: d, c, a, b (two overlapping stars)
- 91: e, d, c (set lower), b, a
- 92: e, d, c (set lower), b, a
- 93: e, d, c (set lower), b, a
- 94: e, d, b (two overlapping stars), a
- 95: e, a, then a pair of touching stars with b above and c below
- 96: d, a, b and c (two small stars close together)

87. On 22 October, at $8^h\ 32^m$, only two appeared through thin clouds; the eastern one was 2′ from Jupiter, while the western one was 6′ away. Whether more were present at that time or not, I cannot state for certain.
88. On 23 October, at $7^h\ 24^m$, again only two little stars were seen, and those in the east, of nearly the same size; b was separated by an equal distance, namely 4′, both from Jupiter and from the other, c.
89. On 24 October, at $7^h\ 46^m$, we found three in exactly the same straight line, along the course of the ecliptic. Of these the more distant, 6½′ away, appeared the largest of all, while the nearer, 1½′ from Jupiter, appeared the smallest. The western one, b, stood 3½′ away.
90. On 25 October, at $7^h\ 55^m$, the two eastern ones were separated from each other by a fairly wide interval; the western ones, however, were so close that scarcely any space was noticed between them, except that the upper one seemed to stand a little farther from Jupiter. The outermost, d, was about 11′ away; c, 6′; and those two western ones only 2′.
91. On 26 October, at $5^h\ 40^m$, all four were placed in the east: e was 13′ from Jupiter, d 5′ 40″, c 5′, b 3′.
92. On the same day, at $6^h\ 26^m$, the three nearer ones were parted from one another by equal intervals, namely a single minute.
93. At $7^h\ 48^m$ all three, d, c and b, were hurrying together toward Jupiter, so that at that time b was 2½′ from a, c 30″ from b, and d 1′ from c.
94. At $8^h\ 45^m$ the two nearer ones, inclining right into conjunction, did not indeed cover each other, but they almost touched. Their interval, as far as could be gathered, was only 10″. A sight of this kind, than which nothing is more beautiful, is certainly very rarely observed. [Margin: A very delightful sight.]

95. On 27 October, at 7^h 50^m, the Jovial Saturn, the outermost of all, was seen not indeed nearer to Jupiter, but smaller than on the day before. In the west, again, two, 3′ from Jupiter, were joined so closely that they formed, as it were, plainly one and the same oblong little star. [Margin: A very close conjunction of Jovials.]
96. At 8^h 55^m on the same day, b and c were now 30″ apart from each other.

On 28 October the harshness of the air prevented observation.

97. On 29 October, at 7^h 32^m, the distance ab was observed to be 1½′; bc, 6½′; ad, 3′.
98. On 30 October, at 9^h, none were visible apart from two small ones, because little clouds had come in between.
99. On 31 October, at 7^h 32^m, we saw three, forming a straight line around Jupiter, in this order: b was 3′ away from Jupiter; c, 8′; and d, 7′.

On 1 and 2 November a rainy sky prevented us from attending to observations.

100. On 3 November, at 7^h 10^m, all four showed almost the same size. The three nearer to Jupiter were also set nearly equally apart from one another, namely by 2′, as they were from Jupiter as well, except that b was 30″ nearer to c. The outermost appeared to be 13′ away.

On 4, 5, 6 and 7 November the air was not at all clear.

101. On 8 November, at 5^h 30^m, the middle one, c, the smallest of all, rose a very little toward the north, and stood as far from Jupiter as b did, namely 4′; but d was separated from c by only 3′.
102. On 9 November, at 6^h in the evening, all were in the east. The second from the outermost had a southern latitude; the two nearer ones were wonderfully diminished, and seemed to stand an equal interval from each other and from Jupiter. But d was 2½′ distant from c, and d from e, 4′. [Margin: All the little stars seen in the east.]

On 10 and 11 November Jupiter entirely denied us any sight of itself.

103. On 12 November, at 5^h 30^m, we found three fairly bright ones; the fourth, however, almost escaped the eye. Their order was this: e was at least 12′ away from Jupiter; d, 8′; c, 3′; but b only a few seconds.
104. On 13 November, at 6^h 45^m, all of them crowded around Jupiter in a straight line

Diagram. Engraved plate, fig. OOO: *Observations of the Circumjovials*, boxes 97–121. The plate is ruled into two columns of numbered boxes: 97–109 down the left column, 110–121 down the right. Each box shows Jupiter as a disc lettered a, with the box number engraved above the letter, and the companions as small stars lettered beside it; some boxes show further stars above or below the line of the companions. The engraved title runs across the head (”Circumiovialium”), with ”Obcervatio” over each column. Signed at the foot left ”fig. OOO.” and at the foot right ”Aut. Sc.” (engraved by the author). Bodies are listed left to right as engraved.

- 97: d, a (disc marked with the sign of Jupiter, ♃), b, c
- 98: c, a, b
- 99: d, a, b, and an unlettered star
- 100: e, a, b, c, d
- 101: d, c, a, b
- 102: e, d, c, b, a
- 103: an unlettered star at the far left, then a, b, c, d
- 104: e, d, c, a, b
- 105: d, c, a, b; below at the left, three unlettered stars
- 106: c, a, b
- 107: d, c, a, b
- 108: d, a, b, c
- 109: a larger box; in its upper line a star lettered g, the word "fixa" or "fixæ" (fixed star or stars) [?], and a star lettered f, then the number; in its lower line a star labelled h, the caption, then e, d, a, b, c
- 110: a star lettered e and labelled "fixa", then d, c, a (disc marked ♃), b
- 111: a star lettered e and labelled "fixa", then d, a, b, c
- 112: e, d, a, b, c
- 113: a star lettered e and labelled "fixa", then a, b, and c and d (two stars close together); at the right edge of the frame two stars with a word set vertically between them, "fixa" or "fixæ" (fixed stars) [?]
- 114: e, a, b (set higher), c, d
- 115: d, c, b, a, with a large unlettered star below the disc; to the right, five unlettered stars and the word "fixa" (the Toronto copy: "fixæ") [?]; a six-pointed star (unlettered) stands at the right edge of the frame
- 116: d, c, a, b
- 117: the number above an unlettered star, with another unlettered star at the top left; in the line below, e, d, a, b, c; below these, two unlettered stars
- 118: d, a, b and c (two stars close together)
- 119: d, a, b and c (two stars nearly overlapping)
- 120: d, e, a, b and c (two stars overlapping)
- 121: c, a, b

and indeed in their distances they held the following arrangement:[31] b seemed to have moved 3′ away from Jupiter; c, 2′; d, 5′; and e, 11′.

105. On 14 November, at $5^h\ 26^m$, Jupiter had three satellites. The more distant eastern one stood as far from c as c stood from Jupiter, namely 4′, and it inclined a little toward the south. The western one, however, the smallest, was only 1½′ away.

106. On 15 November, at $5^h\ 20^m$, only two appeared: c at a distance of 6′, and b at 5′.

[31] begins on PDF 754

107. On 16 November, at 6^h 22^m, Jupiter was found in conjunction with two fixed stars (which, however, are not drawn in the figure). The arrangement of the Jovials was as follows: c stood 3′ from Jupiter, and 4′ from the other; b, in turn, stood the same interval from Jupiter as well.
108. On 17 November, at 7^h 10^m, b was 2′ away from Jupiter; c, 9′; and d, 4′.
109. In the year of Christ 1643, on 2 October, at 10^h, three Jovials were seen around Jupiter, and four fixed stars as well, in exactly the order shown in the figure. The western one, d, was 3′ from Jupiter; b, the smallest of all, 1′; and c, 9′. [Margin: In the year from the birth of Christ 1643.]
110. On 3 October, at 10^h 5^m, two little stars were found on Jupiter's right side, but only a single one on its left, at these distances: ab was 8′; ac, 2½′; cd, 3′; de, 8′.

On 4 October no favourable weather presented itself.

111. On 5 October, at 9^h 25^m, two again accompanied Jupiter on the west and a single one on the east; for the fourth, e, was one of the fixed stars, as the following observations also clearly proved. The more westerly one, which on the preceding day had been only 8′ away, was now 10′ away; b, however, 1′; d, 5; and that fixed star e was 16′ distant.
112. On 6 October, at 9^h 15^m, four circumjovials shone clearly, two on each side; and also eight fixed stars, entirely unknown until now, four on the right and as many on the left, which, however, we did not put in the diagram because the paper was too narrow. The following distances of the companions of Jupiter

were found: ab, 2′; bc, 11′; ad, 2½′; and de the same.

113. On 7 October, at 9^h 15^m, we saw three Jovials toward the west. The first, d, the more northerly, stood off from the middle one, c, by only a single minute; the middle one, c, stood 5′ from b; and b, 3′ from Jupiter.
114. On 8 October, at 9^h 33^m, four little stars were visible. b, the smallest of all, bent away towards the north-east; the rest formed one and the same straight line. d was 8½′ from Jupiter; c, 5′; b, 4½′; and e, the eastern one, 3½′.

On 9 October nothing was observed.

115. On 10 October, at 9^h 14^m, three were found in the east. b, the nearer, which had a southern latitude, was 4½′ from Jupiter; the second, c, 6½′; and d, 8½′. Besides these, six fixed stars also presented themselves; the larger, of the fourth or fifth rank, was observed in conjunction with Jupiter. [Margin: Conjunction of Jupiter and a fixed star.]
116. On 11 October, at 10^h 22^m, all were visible and showed the same brightness and size. b was 4′ away from Jupiter; c, 8′; and d, 10½′.

On the 12th, 13th and 14th, since the sky was veiled with clouds on every side, no observations could be made.

117. On 15 October, at 9^h 10^m, we saw four, placed relative to Jupiter in the following way: b was 5′ from Jupiter; b from c, 3′, that is, the same space

as d was found to stand from Jupiter; the more easterly, e, was 7′ away. Moreover, we also saw some fixed stars around Jupiter, both above and below it, and we have given their order drawn in the accompanying figure as well.

118. On 16 October, at 6^h 30^m, the more distant of the two western ones inclined toward the north, standing only 50″ from the other, b; b in turn was 4′ from Jupiter; and d, 5′.

119. On the same day, at 7^h 30^m, the eastern one appeared a single minute more distant; but the western ones drew closer and closer to each other.

120. At 10^h, again, those two very close ones, which were seen below the perpendicular line, almost touched each other. On the other, eastern side a fourth had now come out, but so faint that it could scarcely be made out. All the rest, however, from one another, as that one from Jupiter, were separated by equal intervals, namely 3′.

121. On 20 October, at 8^h 36^m, only two little stars appeared, with Jupiter between them. The western one, the larger, stood 12′ away; the other, 7′.

122. On 22 October, at 8^h, all four were stretched out in a straight line along the course of the zodiac: the more distant, d, was 13′ from Jupiter; c, 7½′; b, 4½′; and e, 2½′. Three fixed stars as well, fairly far apart from one another, were also seen, as you see.

123. On 24 October, at 10^h, only three formed a straight line, for the other, toward the east from Jupiter, inclined toward the north. The order they kept among themselves, moreover, was this: the western one, b, the largest, was seen 7′ from Jupiter; c, 3′; d, 4½′; and e, 6½′.

124. On 29 October, at 8^h 2^m, the eastern star, the smallest, 2½′ from Jupiter, was raised a little toward the north; the rest ran straight in line with the centre of Jupiter. e, the most distant, was about 14′ away; b, 4½′; and c, 3½′.

125. On 31 October, at 8^h 24^m, all 4 Medicean stars, showing the same size, presented themselves to view in the eastern quarter in this manner. The nearer, northern one was 1½′ from Jupiter, that is, the same interval as c, in turn, was from it; d, 5′; and the outermost, 10′. Besides these, various fixed stars also surrounded Jupiter at that time, as is clear from the drawing.

126. On 1 November, at 7^h 20^m in the evening, three were observed in this position: b stood 2½ away; d, 6′; and e, a single minute from c.

127. On the same day, at 9^h 45^m, a huge change in the Medicean stars was found. For not only had they increased in number, but they were also seen to be very different in position. On each side, indeed, a very close conjunction of two presented itself. The western ones, 2′ from Jupiter, almost touched each other, for they were scarcely 10″ apart, as far as could be gathered by careful inspection. The eastern ones, however, were 6′ from Jupiter, but only 30″ apart from each other. Just as this was very

pleasant for me to watch, so one is not often granted such a feast for the eyes. [Margin: A notable observation.]

But whether one of the western ones, about the time of the earlier observation, had been hidden by the other, or had only just then emerged from Jupiter's shadow, I cannot affirm for certain.[32]

128. On 2 November, at 9^h 30^m, they now presented a far different arrangement; for three were visible in the east, and only a single one in the west. Moreover, the western one, b, was 4′ from Jupiter; e, 10′; but c and d were separated both from each other and from Jupiter by an equal interval, namely of one minute. It should be noted, however, that at this very time six fixed stars of differing magnitude were observed around Jupiter. Yet I considered it superfluous to put them in the present diagram, since I have already given those very stars drawn in chapter IV, page 64.

129. On 3 November, at 9^h, only three stood beside Jupiter. The middle one, 1½′ from Jupiter, turned aside toward the south; the two outer ones, however, attended on their prince in a straight line: d was 4′ away, and b 2½′.

130. On 7 November, at 7^h, the western one, b, was found at a very great distance from Jupiter, about 14′; c, however, at 3′; and d, 5½′.

131. On 9 November, at 10^h 5^m, the little stars in the west were separated from each other by the same interval as b was from Jupiter, namely 5′. The nearer eastern one, however, seemed to be only 2′ away, and the farther, 11.

132. On 10 November, at 9^h 15^m, b, the smallest, clung very closely to Jupiter on the left, so that it was no more than 30″ from it; c, however, the largest, was seen 5½′ away. On the other side, two, standing off 1′, had moved 1½′ away from Jupiter.

133. On 11 November, at 6^h 15^m in the evening, only a single star attended Jupiter on each side: b was 3½′ away, and c, 5′.

134. On 3 December, at $7½^h$ in the evening, the following distances of the Jovials were noted: ae, 14′; ab, 1′; bc, 40″; and cd, 7′.

135. On 4 December, at 7^h 20^m, the western ones were seen set off at an equal interval, namely 4½′, both from each other and from Jupiter; but the eastern one had come a little nearer to Jupiter than on the preceding day, namely 2′.

Diagram. Engraved plate, fig. PPP: *Observations of the Circumjovials*, boxes 122–151. The plate is ruled into two columns of numbered boxes: 122–135 down the left column, 136–151 down the right. Each box shows Jupiter as a disc lettered a, with the box number engraved above the letter, and the companions as small stars lettered beside it; some boxes show further, unlettered stars. The engraved title runs across the head ("Circumiovialium"), with "Obcervatio" over each column. Signed at the foot left "Aut. Sculps." (engraved by the

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author), with the caption "fig. PPP." at the foot right. Bodies are listed left to right as engraved.

- 122: e, a (disc marked with the sign of Jupiter, ♃), b, c, d; at the right of the box, by the column rule, two unlettered stars, one high and one low
- 123: e, d, c, a, b
- 124: an unlettered star at the far left, then d, a, b, c
- 125: e, d, c, b, a; three unlettered stars (upper right, lower left, lower middle)
- 126: e and d (two stars close together), a, b
- 127: d and e (two stars close together, d above), a, b and c (two stars nearly overlapping, b above)
- 128: e, d, c, a, b
- 129: d, c, a, b
- 130: d, c, a, b
- 131: e, d, a, b, c
- 132: e and d (two stars close together), a, b, c
- 133: c, a, b
- 134: e, a, b and c (two stars close together, b above), d
- 135: an unlettered star at the far left, with a short stroke above it that is not resolved [?]; then a, b, c; below the disc, d
- 136: an unlettered star above the disc; e (small, close to the disc), a (disc marked ♃), b, c, d
- 137: e, d, a, b, c
- 138: e, a, b, c, d
- 139: d and e (two stars close together, d above), c, a, b
- 140: e, d, c, a, b
- 141: e, a, b, c and d (two stars close together)
- 142: d, c, b (small, close to the disc), a
- 143: e, a, b and e (two stars close together, as engraved), d
- 144: c, b, a
- 145: e, d, a, b and c (two stars stacked, b above)
- 146: a, b, c, d, e
- 147: d, a, b, c
- 148: d, a, b, c
- 149: a, b (small), c, d
- 150: e, a, b, c
- 151: e, d and c (two stars close together), b, a

136. On 11 December, at 7^h 18^m, a very tiny one clung closely to the eastern edge of Jupiter; in the west three accompanied Jupiter, of which d stood 13½′ off; the next, c, 8′; and b, 4′. [Margin: Jupiter grazed a star with its edge.]

137. On 13 December, at 7^h 15^m, a small one was again almost touching Jupiter's western limb; c, however, was removed a fair way off, namely 10′; in the east, d was 3′ from Jupiter, and e, 5.

138. On 25 December, at 6^h in the evening, all four, of almost the same size, were observed in exactly the same straight line: b was 5′ from Jupiter; c, 8′; d, 12′; and e, 4′.
139. On 30 December, at 4^h 45^m in the afternoon, all were indeed present again, but they were much diminished in brightness and size. The order they kept was this: b was 6′ from Jupiter; c, 2′; e, 4½; and e went 20″ from the other one, d.
140. In the year 1644, on 2 November, at 10^h, the arrangement of the stars was this: the western one was 6′ from Jupiter; c, 3½′; d, 7′; and e, 16′. [Margin: In the year 1644 from the birth of Christ.]
141. On 13 November, at 9^h 25^m, e, in the east, was 1½′ from Jupiter; b, 3½′; c and d, however, standing 6′ off, were so close to each other that there was almost no interval at all.
142. On 14 November, at 11^h, three were detected in the east. The nearest of them, the smallest, turned aside toward the north and was only 30″ from Jupiter; the next was 3½′ from b, as it was also from the more remote one.
143. On 19 November, at 9^h 45^m, the slowest of the Jovials was seen at almost its farthest elongation from Jupiter, since it was 14′ away from it. In the west, b and c, 4′ from Jupiter, were very close. d, again, seemed to be 6′ from these. [Margin: The Saturn of the Jovials, observed at almost its greatest distance.]
144. On 22 November, at 9^h 45^m, only two came into view, in the eastern quarter: the outer one, c, was 10½′ away; b was so tiny that it almost escaped sight, and was no more than 1½′ from Jupiter.
145. On 23 November, at 10^h, two on each side were ob-

served: the western ones were found under a perpendicular line, no more than 15 or 20″ apart; the other two, in the east, stood a good distance from each other, namely 9′. The nearer one was very faint.

146. On 26 November, at 8^h, all four were moving in the same straight line: the two nearer ones were separated by an equal interval, namely 2′, both from each other and from Jupiter; but d was removed 10′, and e about 16′, from their principal.
147. On 30 November, at 10^h, we noticed only three, in this position and at these distances: ad was 11′; ab, 3′; and bc, 4′.
148. On 3 December, at $7½^h$, three were extremely conspicuous in brightness and size. The eastern one was seen at its greatest remove, almost 17′. The nearer western one, however, was seen to be 4½′ from Jupiter, the more remote 12′.
149. At 9^h 45^m on the same day four were seen; but b had only just extricated itself from Jupiter's shadow.
150. On 12 December, at 8^h, four attended Jupiter, in this order: e was 3′ from Jupiter; b, to the north, 2½′; c, 5′; and d, 15′.

151. On 20 December, at 10^h 15^m, all four again presented themselves in the east; d inclined toward the north, while the rest formed a straight line. At that time b was 2½′ from Jupiter, c 5′, d 9′, and e about 16′.

At last, then, with our observations both of the solar spots and of the Jovials set before the eyes of all, we had fully resolved to add not even one word more, and to put an end to this appendix to the *Selenographia* as well. But since very recently and unexpectedly we were able to notice an instance of closer conjunctions of Jupiter (a spectacle that in these regions will certainly not return except after many periods of years, so that scarcely any of us mortals now alive will be granted to behold it), and to record it with the necessary care, we thought it worth the effort that the reader eager for the science of the stars, and above all the mathematicians,

thoroughly versed in astronomy (to whom the worth and usefulness of this matter are most evident), should be made sharers in that contemplation, as a crowning conclusion. We were moved to this labour, moreover, above all because this observation will throw much light on the method that we taught above must be followed for occultations and transits of stars, and will make much plainer everything there that may still seem somewhat obscure to someone, or that I have, contrary to expectation, stated less clearly.

But to deal with the matter in a few words, here at once is the observation itself of the conjunction of Jupiter and the Moon. It certainly deserves to be recorded all the more, the more rarely it is ever met with in that manner, since it occurred at the time of the true first quadrature, that is, about the phase of the bisected Moon. Here also is the whole procedure that we carefully applied in making the observation. [Margin: Observation of the conjunction of Jupiter and the Moon.]

First, we not only took the altitudes of certain stars, namely in order to derive the true time, but also carefully recorded the various elongations of Jupiter from the Moon's upper cusp, or from its limb, against an infallible standard, namely the distances of certain lunar spots. And we determined each and every one of these elongations even to the minutes (which, once the lunar diameter alone is known, is all too easy to accomplish). Nor did we by any means neglect either those lunar spots with which Jupiter formed an exactly straight line at each moment of observation, or those spots, too, which then presented themselves under the same perpendicular line; for by their help the vertical degree of the Moon and the inclination of the cusps always become correctly known. And it is of the greatest concern to all of us not to be ignorant of this in general. For on this alone depends the entire foundation and certainty of this business: once these things are properly attended to, the errors that have sometimes been committed in such observations up to now are recognised and exposed with no labour at all. And so at last, having recorded everything with the care required, we set it out in order in a table, as is our custom, adding a figure of the transit itself, or conjunction. [Margin: Figure of the Jovial transit.]

TRANSITUS JOVIS, GEDANI

The transit of Jupiter, observed at Danzig in the year of the Christian era 1647, on April 12, new style, in the evening.

Observation	Altitudes of Arcturus taken with the quadrant	Computed time	Which spots were observed under the same perpendicular line; which degree was vertical, and how great the inclination of the cusps was	Distance of Jupiter from the Moon's upper cusp, determined accurately both from the distances of the spots and also to the very minutes	With which lunar spots Jupiter, observed at each time, formed an exactly straight line
1	39° 40′	$9^h\ 15^m\ 40^s$			
2	40° 5′	$9^h\ 19^m$	Byzantium and Mons Æmus. From this it is clear that the 40th degree of the Moon was vertical, so that the upper cusp, namely, stood 8° away, towards the west.	The distance was found to be about 45′.	
3	41° 5′	$9^h\ 26^m\ 12^s$			
4		$9^h\ 38^m\ 10^s$		The distance was about 40′.	
5		$9^h\ 59^m$	Mons Ligustinus and Insula Besbicus; at which time the 47th degree was vertical, while the upper cusp was elongated 15° from the zenith.	A distance of about 36′ was noted.	Jupiter, Insula Besbicus and Mons Herculis formed the same straight line.
6	45° 58′	$10^h\ 4^m\ 25^s$		The distance equalled the diameter of the Moon, that is, according to Kepler, 32′ 42″.	Jupiter, Insula Besbicus and Insula major Caspii.
7	48° 5′	$10^h\ 22^m\ 23^s$		Jupiter was as far from the Moon's upper cusp as the said cusp was from Insula Cyprus, that is, 22′.	Jupiter, Mons Argentarius and Insula Major Caspii.
8	49° 40′	$10^h\ 37^m\ 7^s$		The distance was equal to the distance between the upper cusp and Mons Sipylus, that is, 18′.	Jupiter, Mons Ligustinus and Insula Apollonia major; at which time Jupiter, together with Mars and the Moon's upper cusp, stood exactly in a straight line. The distance between Jupiter and Mars, found with the smaller radius, was about 2° 17′.

Observation	Altitudes of Arcturus taken with the quadrant	Computed time	Which spots were observed under the same perpendicular line; which degree was vertical, and how great the inclination of the cusps was	Distance of Jupiter from the Moon's upper cusp, determined accurately both from the distances of the spots and also to the very minutes	With which lunar spots Jupiter, observed at each time, formed an exactly straight line
9	51° 0′	$10^h\ 50^m\ 20^s$		The distance was now less than the lunar diameter: as far, namely, as Besbicus from the upper cusp; that is, it was estimated at 13′.	Jupiter, Mons Ligustinus and Byzantium.
10	52° 3′	$11^h\ 1^m\ 24^s$	Mons Serrorum and Insula Apollonia major. The 53rd degree of the Moon was therefore culminating, while the cusp was 21° from the zenith	The distance did not exceed the interval between Insula Besbicus and Mons Serrorum, that is, 12′ 30″.	Jupiter, Insula Apollonia major and Mons Æmus.
11	52° 20′	$11^h\ 4^m\ 49^s$		Jupiter was elongated from the Moon's upper cusp by no wider interval than the said cusp seemed to be distant from Mons Argentarius, that is, 8′ 30″	Jupiter, Insula Cyanea and Mons Æmus.
12	52° 43′	$11^h\ 9^m\ 19^s$		The distance between Mons Æmus and the Moon's upper cusp exactly equalled the distance between Jupiter and the same cusp, that is, about 8′.	
13		$11^h\ 11^m\ 5^s$		The distance of Jupiter from the cusp was similar to the distance of Mons Carpathes and Insula Besbicus, that is, 6′ 30″.	Jupiter, Mons Serrorum and Apollonia major.
14	53° 10′	$11^h\ 14^m\ 50^s$		At the time, namely, of the true conjunction, Jupiter certainly stood off from the Moon's upper cusp by as great an interval as Mons Serrorum is distant from Mons Argentarius, that is, 6′.	Jupiter, Insula Cyanea and Mons Serrorum.

Observation	Altitudes of Arcturus taken with the quadrant	Computed time	Which spots were observed under the same perpendicular line; which degree was vertical, and how great the inclination of the cusps was	Distance of Jupiter from the Moon's upper cusp, determined accurately both from the distances of the spots and also to the very minutes	With which lunar spots Jupiter, observed at each time, formed an exactly straight line
15		$11^h\ 21^m\ 30^s$		The distance of Jupiter from the Moon's upper cusp again came close to the distance between Insula Besbicus and Mons Carpathes, that is, 7′.	Jupiter, Mons Serrorum and Insula Besbicus.
16	Altitude of Lyra	$11^h\ 23^m\ 30^s$		No greater distance of Jupiter from the Moon's upper cusp was found than the distance between Insula Besbicus and Mons Serrorum, that is, 8′ or a little more.	Jupiter, Mons Carpathes and Mons Sipylus.
17	34° 25′	$11^h\ 30^m\ 9^s$		Jupiter was removed from the Moon's limb by as great a space as Insula Apollonia seems to be distant from Mons Serrorum, that is, 9′.	Jupiter, Mons Serrorum and Mons Argentarius.
18	36° 0′	$11^h\ 41^m\ 39^s$		Jupiter was elongated from the Moon's limb by no greater interval than Insula Besbicus is found to stand from the Moon's upper cusp, that is, 13′.	Jupiter, Mons Carpathes and Mons Argentarius.
19	38° 33′	$11^h\ 59^m\ 15^s$	Insula Apollonia major and Mons Carpathes were found under the same perpendicular line, so that it is certain that the 55th degree was vertical, and that the cusp was 23° away from the vertical point, or zenith.	The distance between Jupiter and the Moon's limb was again equal to the distance between its upper cusp and Mons Sipylus, that is, 18′.	Jupiter, Mons Æmus and Mons Argentarius.

Diagram. Engraved plate of the transit of Jupiter past the Moon. The engraved title, centred at the top, reads: *Transit of Jupiter, at Danzig, observed in the year from the birth of Christ 1647, on April 12.* Below it a half-illuminated Moon, shaded with its spots, stands in the lower middle of the plate, its upper cusp pointing up and to the left. Jupiter's successive positions are drawn as

small numbered circles running in a curve from the upper left, across the top of the Moon, down to the right; most circles have one or more small stars beside them. A faint line joins the circles from 2 to about 9, and a dotted line runs from each circle down to the Moon's upper cusp or limb. A small planetary sign stands above circle 14.

- Top centre: engraved title (four lines), as above.
- Upper left, running down to the right: 2, 4, 5, 6, 7, 8, 9 (each beside a circle).
- Above the upper cusp, left to right: 10, 11, 13, 14.
- Above circle 14: ♂ (Mars).
- Right of the cusp, running down to the right: 15, 16, 17, 18, 19.
- Lower left: Fig. [?]
- Lower right: Autor Sculpsit. (*The author engraved it.*)

For this purpose, moreover, we went to the trouble of drawing an entirely new and smaller image of the Moon, one never shown by us before nor attempted by anyone — and certainly not without remarkable labour, if one may say so. We did this because it allowed all of Jupiter's distances from the Moon to be taken in on a single small page, which would have been altogether impossible had we used the larger face of the Moon. Even so, the spots and their proportions are sketched in this figure with exactly the same care as was taken in all the other, larger ones, so that we have left out no spot at all, however tiny. (You, reader, will judge the difficulty of the work without my saying so.) [Margin: Why the author drew an entirely new image of the Moon.]

I would like you to notice, however, that the dotted lines running from the Moon's limb to each position of Jupiter show with which spots Jupiter was seen in the same line at each station, while the numbers set beside those lines indicate the order of the observations. In this way the table itself can be compared with the figure attached to it without any trouble.

You should also note here that this figure shows exactly the inclination which the Moon itself actually displayed at the time of the true conjunction (that is, while it formed one and the same straight line with the boundary of light and shadow, and was no more than 6′ distant from the cusp). [Margin: The inclination of the figure.] We have disregarded the fact that the inclination was found to be smaller at the beginning of the observation and greater towards its end; but on this occasion the Moon's inclination nevertheless changed only very slowly, and this because the angle of the west [angulus occidentis] varied little.

Further, to confirm once again what was said about the diameters of the planets in chapter 55, fol. 439, and chapter 56, fol. 477, we observed Jupiter's diameter, with the help of the spots, as accurately as it could be done. [Margin: The author again measures the visible diameter of Jupiter.] We found it, then, no larger than Mons Cragus, in Asia Minor, which lies not far from the mountains Sipylus and Didymus; and the diameter of this Mons Cragus, carefully weighed, barely equals 1/34 of the diameter of the whole Moon.

[Margin: How large it was found to be.] Hence, given the Moon's diameter according to Longomontanus as 33′ 58″, Jupiter's diameter comes to barely a single minute; but according to Kepler, given a diameter of 32′ 42″, only 57½″. But according to Gassendi's proportion, with a lunar diameter of 31′

6″, its diameter must be said to come to only 55″ — Jupiter, that is, being near its apogee. From this it is now more than abundantly clear that the visible diameter of Jupiter is found to be far smaller indeed than all our predecessors have so far thought. [Margin: The diameter of Jupiter far smaller than they ever thought.]

Lastly, it should be noted that although the Moon was by then well enough increased in light, and very close to Jupiter, the Jovials nevertheless showed themselves very clearly. [Margin: The Jovials shone out clearly at the time of the transit.] At first, indeed, only two struck the eye; but about the middle of the observation a third, the smallest of them, then first emerging from Jupiter's shadow, appeared no less plainly. All three of them glittered towards the west: the outermost stood six diameters of Jupiter away from its prince, the middle one one diameter, and the nearest a semidiameter or somewhat more. [Margin: The order of the Jovials.] All this that has just been said can be plainly seen in the attached figure, around Jupiter, which here likewise shows its true size as measured against the spots.

This, then, is what we wished to set out here as briefly as possible, and to publish about this meeting with Jupiter, which was a little out of the ordinary. Since, my reader, nothing at all now seems to remain that bears on our present purpose, we now lay down our brush from these observations of ours, the selenographic ones and all the others alike. We promise ourselves with confidence, from the kindly and well-disposed nature of your mind, that you will turn eyes upon our work as intent as those we have so far kept always fixed on the heavens, so that we might come to know the things we have frankly shared with you. Once we know this, our spirits will certainly be strengthened, so that, with God and in good time, we may hunt out more things of this kind in private with the greatest zeal, and with the best will make them public.

FINIS.

The End.

NON NOBIS, SED NOMINI TUO, DOMINE, GLORIA.

Not to us, but to your name, Lord, be the glory.

TU NOS CREASTI, TU OMNIA.

You created us; you, all things.

Diagram. Engraved plate: a full disc of the Moon drawn in outline only, its spots, mountain ranges and craters traced as closed contours and small rings, with several straight and curved ridges, a group of rays spreading from a large ring in the left half and from a smaller ring at the left edge, and a few small hatched marks. No names are engraved on the disc. The engraved title across the top reads: *Primary Figure of the Phases and Lunations.* Below the disc stand two scale bars.

- Top: Figura Primaria Pha[?]ium et Lunationum. (*Primary Figure of the Phases and Lunations.*)
- Lower left: Fig. T.∗.
- Lower right: Aut. Sculps. (*The author engraved it.*)
- Over the left scale bar: Semidiameter Lunæ. (*Semidiameter of the Moon*), divisions marked 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, the first division subdivided by small ticks.
- Over the right scale bar: Digiti Ecliptici. (*Ecliptic digits*), divisions marked 1, 2, 3, 4, 5, 6, each halved by a shorter tick.
- Near the centre of the disc: minute lettering and figures round a small hatched lozenge inside a circle — [?] [?] [?] [?].

Diagram. Engraved plate: a full disc of the Moon drawn in outline only, its spots, mountain ranges and craters traced as closed contours and small rings, with several straight ridges, a group of rays spreading from a large ring in the left half and from a smaller ring near the left edge, a bright ring low in the disc from which long rays run up to the left and right, and a few small hatched marks. No names are engraved on the disc. The engraved title across the top reads: *General Figure of the Full Moons.* Below the disc stand two scale bars.

- Top: Figura Pleniluniorum Generalis. (*General Figure of the Full Moons.*)
- Lower left: Fig. T.t.∗∗
- Lower right: Aut. Sculp[[s/r]]. (*The author engraved it.*)
- Over the left scale bar: Semidiameter Lunæ. (*Semidiameter of the Moon*), divisions marked 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, the first division subdivided by small ticks.
- Over the right scale bar: Digiti Ecliptici. (*Ecliptic digits*), divisions marked 1, 2, 3, 4, 5, 6, each halved by a shorter tick.
- A little left of and below the centre of the disc, minute lettering round a small circle enclosing a hatched mark: Au[[s/f]]t. (*South*) on its upper left, Boreal. (*North*) on its lower right, and small figures beside it — [?] [?] [?].

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AD LECTOREM.

To the Reader.

On the errors left behind, that they may be kindly removed.

I have been extremely busy with the continuous work of celestial observation, with the very heavy labour of engraving so many figures, with composing and rewriting what is read here, and also with rereading and correcting what had been printed (is that not business enough for one man?). So I was by no means able to avoid errors in such a way that this work of ours should come out

without them (and without errors it is scarcely granted to any author, even one less distracted, to publish a book). These errors, however, I have at last noticed fairly well, now that I am less busy, and they are set out here in order, to this end: that I may most courteously ask you, my reader, to correct them, not counting it against me as a fault but rather favouring me with your indulgence. As I am, so I shall be: always most eager both for the public good and for your honour. These, I say, are to be corrected as follows:

Page	Line	Printed	Correction
14	12	*cavo-planâ*	*cavo-plano*
17	31	after *internarum*	insert *adhibeat*
25	16	*quæ*	*qui*
27	8	*variæ*	*varias*
28	5	*r*	*u*
30	25	*d.g*	*d. e*
	26	*e.f*	*c f*
33	15	*intricarum*	*intricatarum*
34	2	*visus*	*visas*
36	7	*orbiculatas*	*orbiculares*
37	14	*convexi*	*convexæ*
40	11	*quia*	delete
56	22	*judicio*	*indicio*
61	10	*altiores*	*altiorem*
63	21	after *spatio*	insert *12. circiter*
64	[?]	*propressæ*	*progressæ*
79	13	*sicut*	*sunt*
86	19	*exeunte*	*orientali*
92	15	αυτοφια	αυτοψια
100	29	*nequies*	*nequis*
125	5	*quas*	*quæ*
129	31	*lib. 5*	*6*
134	17	*infirmum*	*infimum*
137	10	*calorem*	*colorem*
139	4	*idicabitur*	*judicabitur*
	15	*eaq;*	*easq;*
143	2	*illuminatæ*	*illuminati*
145	28	*imminet*	*immineat*
151	29	*sparget*	*spargat*
167	20	*&*	*ut*
169	4	*me*	delete
183	28	*Syzigiæ*	*Syzygiæ*
185	2	*quæ*	*inter quæ*
		obtinent	*obtinet*
	29	*ante*	*verò*
190	10	*ejus*	*earum*
194	23	*quod*	*quot*
207	14	after *tempore*	insert *ac ne*
217	3	*compendiori*	*compendiosiori*
	penultimate	after *vereor*	insert *dicere*

Page	Line	Printed	Correction
218	18	*subsedere*	*supersedere*
219	3	after *operis*	insert *in*
	4	*potuissem admittere*	*posse admitti*
[?]	9	*fuerint*	*fuerunt*
227	[?]	*moris*	*more*
240	margin	*generali*	*generalis*
248	penultimate	*variatq;*	*varietq;*
251	28	*maculas*	*maculis*
[?]	17	*potuerim*	*potui*
	25	*obtinentia*	*obtinentium*
255	3	*removebantur*	*removerentur*
281	29	*cassam*	*cassum*
292	4	*fit*	*fiat*
299	23	*sit*	*sint*
302	15	*mendabitur*	*mendabuntur*
306	12	*hebitare*	*hebetare*
308	11	*tempus*	*tempore*
319	18	*intactu*	*intacta*
327	last	*hæc*	*hos*
330	18	*aliquod*	*aliquot*
333	29	*deprehendes*	*deprehendas*
341	19	after *stabiliuntur*	read *Quem*
	26	*fuimus*	*fuerimus*
	28	*tempore*	*tempori*
344	17	*unquam*	*nunquam*
352	13	*hos*	*hi*
354	7	*informandi*	*informandæ*
357	31	*nivi*	*nive*
372	3	*cuilibet tironi*	*cujuslibet tironis*
406	32	*quæras*	*quæratur*
	33	*transferatur*	*transferas*
309	2	*Utilitatæ*	*Utilitate*
411	26	after *iterum*	insert *se*
435	26	*favit*	*favet*
441	3	*initiatione*	*imitatione*
	11	*tum*	*tam*
457	[?]	*contentum*	*contentos*
458	30	*par*	*paria*
460	6	*limbi*	*limbo*
476	23	*factum*	*factam*
480	20	*insiderit*	*insederit*
	penultimate	*nunquam*	*unquam*
481	23	*minùs*	delete
484	[?]	*relicto*	*relinquendo*
486	3	*aliter*	*alter*
493	11	*utilissimum, accommodatissimum*	*utilissima accommodatissima*
	12	*videtur*	*videntur*
494	23	*sujiciantur*	*subjiciantur*
	28	*sectiones*	*sectionis*

Page	Line	Printed	Correction
499	last	*protahantur*	*protrahantur*
504	6	*haram*	*harum*
505	margin	*redux est*	*redux ex*
521	5	*subsequuta*	*subsequutus*
	10	*caluerunt*	*coaluerunt*
539	6	*illa*	*ille*
540	24	*aliquod*	*aliquot*
544	last	*sideriæ*	*sidereæ*
551	1	*Ellipseos*	*Eclipseos*
559	8	*phasis*	*phases*
560	30	*reflectio*	*reflexio*

If any others still remain, they will likewise be corrected, if need be; although some things which may perhaps seem to someone worthy of correction will scarcely be such, provided that our mind is heeded as intent on matters rather than on words. Farewell.

The End.

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___[34]

___[35]

[33] Blank verso of the last leaf; the printed facing side shows through in mirror image. A few faint pen or pencil strokes in the right half are unread [?].

[34] Blank endleaf.

[35] Blank endleaf.