Institutio astronomica iuxta hypotheseis tam veterum, quam Copernici, et Tychonis. Dictata à Petro Gassendo regio matheseos professore. Eiusdem oratio inauguralis iteratò edita

[Astronomical Instruction according to the Hypotheses of the Ancients, of Copernicus, and of Tycho]

(1647)

by Pierre Gassendi (Petrus Gassendus, 1592–1655)
Translation by Scott Weisman

Ars Astronomica
2026

”Institutio astronomica iuxta hypotheseis tam veterum, quam Copernici, et Tychonis. Dictata à Petro Gassendo regio matheseos professore. Eiusdem oratio inauguralis iteratò edita,” published in 1647, is in the public domain. All translations, original additions, including illustrations, commentaries, and summaries, are copyright.

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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

The standard astronomy textbook of the mid-seventeenth century, dictated by Pierre Gassendi to his students as Royal Professor of Mathematics in Paris. It teaches the doctrine of the sphere, then the theories of the Sun, Moon and planets, and sets the Ptolemaic, Copernican and Tychonic world systems side by side, weighing each against observation and Scripture. Reprinted many times across Europe, it shaped how a generation learned the heavens. The volume closes with Gassendi's inaugural oration on the dignity of mathematics. A companion to his *Life of Tycho Brahe*.

A note on the translation process

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

This edition has been checked at citation grade. Every part of the translation was first compared, clause by clause, against a line-by-line transcription of its own page, and each divergence was settled before the work moved on. Then, on a stratified sample, the layer a citing reader depends on — figures, numbers, names, and every letter the transcription left undecided — was read again, point by point, from the original page by readers given no sight of either the transcription or the translation. Every disagreement in that layer, including whether a passage is present at all, was settled against the page before publication, and none was left open.

What that does and does not mean. The independent re-reading is a claim about those points in a sample, not about every line: it did not re-read whole pages, and a point it did not reach is neither confirmed nor denied. The clause-by-clause comparison covered the whole translation, but it checks the English against a transcription, not against a second reader. Where the page itself will not settle a reading, this edition withdraws rather than guesses: a bracketed pair marks a genuine ambiguity the original cannot decide, and a question mark a character that could not be read. Those marks are deliberate refusals, and they are worth more than the confident readings they replace.

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

Images by courtesy of the Bayerische Staatsbibliothek München (Münchener DigitalisierungsZentrum) and of the Biblioteca Nazionale Centrale di Roma via Google Books and the Internet Archive.

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*

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°
♓	Pisces	the Fishes	330°–360°

The Sun, Moon and planets.

	Latin	English
☉	Sol	the Sun
☿	Mercurius	Mercury

	Latin	English
♀	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.

INSTITUTIO ASTRONOMICA

Astronomical Instruction

according to the hypotheses both of the ancients and of Copernicus and Tycho Brahe.

Dictated by Petrus Gassendus [Pierre Gassendi], Royal Professor of Mathematics.

Together with his Inaugural Oration, issued a second time.

Diagram. The printer's device: an oval woodcut showing a seated female figure holding a branch, resting on a heap of arms, within a strapwork frame. The legend runs round the oval, and a small cartouche stands at its foot.

- Right side of the oval: PAX CERTA MELIOR ("A sure peace is better")
- Left side of the oval: SPE[R?]ATA VICTORIA ("hoped-for [?] victory"; the fourth letter of the first word is weak and is read as a conjecture)
- Cartouche at the foot: TYPVS [?]ACIS ("The image of …"; the first letter of the second word is hidden)

Paris,

at the shop of Ludovicus de Heuqueville [Louis de Heuqueville], in the rue Saint-Jacques [viâ Iacobeâ], at the sign of Peace.

1647.

With privilege.

To the Most Eminent Cardinal of the Holy Roman Church, Ludovicus Alphonsus Plessaeus Richelius [Alphonse-Louis du Plessis de Richelieu], Archbishop of Lyon, Primate of the Gauls, Grand Almoner of France,

Pierre Gassendi wishes well-being [Greek: ΕΥ ΔΙΑΓΕΙΝ (eu diagein, "to live well")].

I offer you, Most Eminent Cardinal, a specimen of that deference of mine, by which you may judge that what you thought fit to require of me has been carried out. The fact is that, by virtue of the charge of the Royal College that is entrusted to you, you had brought it about that the Most Christian King should appoint me to the professorship of mathematics. For my part I refused, for a long time indeed and firmly; but, prevailed upon on the one side by your insistence and on the other by the veneration in which I hold you, I at last took up the office, as you had ordered. But when, in keeping with your wishes and those of others, I had begun with a com- pendious Instruction in Astronomy, it next came about that the bookseller, aware that copies of it were being procured in various ways, insistently demanded that I allow him to have it printed. And I did consent, but with this purpose: that this little work, whatever it might be worth, should carry your illustrious name at its head, so that everyone would understand that it was you who had been the occasion of it.

This, then, is the very specimen by which I give you assurance that I have obeyed you; and I offer it while, because of an illness now of long standing, I am taking a rest. For it is now a long while since that chest complaint of mine began to grow so much worse that, besides keeping a moderate diet, I must also take rest to soothe it. Meanwhile, however, I cannot help recalling with

the greatest pleasure that great kindness of yours with which you deigned to show your concern for my health, both while you were present in the City and when, about to leave it, you wished to take me with you — for I was thinking of my native soil, for the sake of a change of air — had I indeed been able to bear the journey. What is more, on your departure you added this proof of your goodness: although I had in the end taken up the professorship on no other condition than that I might resign it whenever I pleased, without loss of your affection for me, you would not even hear me speak of resigning; and, because I pleaded that there would be an interruption, perhaps a rather long one, if for the reason just set out I withdrew to Provence, you replied that you did not, indeed, dispense anyone from residence, nor grant anyone exemption from duty, but that you nonetheless wished to treat me as an exception.

Nor are these new proofs of your goodwill towards me. Ever since your virtue first shone out in the most holy Desert [Eremo], you have shown me a singular affection. And when, in the ancient manner, you were taken from it to be set over and to govern, as prelate, the metropolitan see of our Province, you both wished me, hesitant as I was, to be kindly summoned to you, and on every occasion made it plain how great your inclination towards me was.

Afterwards, when you had been transferred elsewhere, co-opted into the College of the Purple and raised to various honours, you remained the same towards me. You never allowed anything of that former and most easy familiarity to slacken, and you often let it be known that, absent though I was, I nonetheless clung fast in your very marrow and heart. I gladly recall these things, so as to convey, with all the gratitude of heart I can, that it is not for nothing that I long ago fixed you in my winding breast. But nothing is more pleasant than to recall, besides, what has always produced in me a remarkable admiration of you, and a veneration too.

That, above all, was the candour of your singular mind, by which, incapable of pretence, you always showed yourself the same in public view as in private retreat. True to your noble nature, you never did anything beyond what was seemly; true to your old-fashioned good faith, never anything beyond what was right and just.

From this there always came that sincere and unpainted piety of yours. Holding most tenaciously to the ancient and lawful worship of God, you have always turned away from all novelty and superstition; and just as you never patiently bore those who spread a false varnish over Religion, so you pursued the new Alcibiadeses with wonderful ardour and did not allow them to go unpunished for trampling the sacred Mysteries underfoot. From this came that true and genuine care for the flock entrusted to you. Even while the dread contagion of the plague was raging, you stayed constantly among them, and counted it good fortune to be able to lay down your life for them — an example rare in this Dignity, and a singular proof that you do nothing for the show of a feigned piety, since on an occasion of this kind, surely, the mask is torn away and the reality remains.

From this came that unbroken and lofty constancy with which you allowed the goods of fortune to be snatched from you. On the one hand, you held them of too little account to think you had lost anything of your own, and you did not wish to use against another even the rights that remained intact to you; on the other, declaring that you still had more than enough left, you most wisely refused the most ample benefices [Sacerdotia ampliſſima] that were offered to you from time to time. From this came that heart steadfast in its purpose and steeped in honour, with which, whether sitting in the sacred College or presiding over your own clergy — indeed over the whole Gallican Clergy — you always looked to whatever was worthy of a wise and good man; and with which you always dispensed the various offices entrusted to you under various titles never by favour, but by your own choice, according as each man's diligence was known to you.

But the list would grow far too long if I went through every particular, since this place also requires, rather, that I recount the outstanding love of the liberal arts with which you have always burned — and above all of this one, which consists in the contemplation of celestial things, and than which none can be held more worthy of a free-born man. Indeed, I hardly ever come to you without your asking me something about these matters, or without your rejoicing when you hear of something new, whether found out by observing or deduced by reasoning. That is why I offer you this little work with all the more confidence, as it deals with the very things I have seen you delight to learn. Certainly, even though it contains nothing but the rudiments of the art, I nonetheless conjecture that it will be welcome to you: because you yourself also do not disdain to descend to these things at times; and because, whatever it may be, it is mine, and published for no other end than the one for which you wished it to be dictated publicly — namely, that if it has any talent in it, and is of so happy a fortune, it may be of use to as many people as possible.

For although there exist not a few books on this subject, and most learned commentaries as well, there are nonetheless those who want, besides these, some form of instruction that is somewhat better suited to those not yet initiated and to beginners, that is neither obscure through brevity nor tiresome through length, and that does not, indeed, examine the principal heads of the science in detail, but does at least touch on them.

Yet I am not, for that reason, the man who would profess [?] this work to be of that kind. I call to witness only the ready goodwill with which I wished to oblige [?] the learners: so that they should not be overwhelmed either by the mass of the material or by its obscurity, I made it my aim to state everything concisely, indeed, but as clearly as I could. And I have done this not only for what concerns the Ptolemaic System, or common Hypothesis, whose doctrine of the sphere [Sphæricam Doctrinam] and theory of the planets [Planetarem Theoriam] I have covered in two Books, but also for what concerns the less common Systems, or Hypotheses, of both Copernicus and Tycho, which I have set out in a separate Book. In this I meant to satisfy the wishes of those who

had earnestly asked me about these matters and begged me to gather together, and to state in my own way, what they thought had been presented by others either too diffusely or too confusedly. Whether I have achieved anything of the kind they had anticipated is for them to see and to say. For me it is enough if I win the approval of you alone, and if this little work shows me to have been, as most obedient to you, so most devoted to you. Long life to you, MOST EMINENT CARDINAL, to the great good of the Church, and FAREWELL. Paris, 1647 July 15.

LIBRORVM, ET CAPITVM INDEX.

Index of the Books and Chapters.

LIBER PRIMVS

Book One

De Doctrina Sphærica.

On the Doctrine of the Sphere.

- Chapter I. What a sphere is, and what it is made up of. — page 7
- Chap. II. On the so-called celestial globe, insofar as it is the same as the sphere. — 11
- Chap. III. On the Earth as represented in the middle of the sphere. — 13
- Chap. IV. On the axis and the poles that are called "of the world". — 16
- Chap. V. On the circles of the sphere, and first on the horizon. — 18
- Chap. VI. On the meridian. — 20
- Chap. VII. On the equator. — 22
- Chap. VIII. On the tropics. — 23
- Chap. IX. On the polar circles. — 25
- Chap. X. On the colures. — 26
- Chap. XI. On the zodiac and the ecliptic. — 27
- Chap. XII. On the signs of the zodiac. — 29
- Chap. XIII. On certain other circles conceived in the sphere, such as those called verticals, and the circles of altitude, of distance, of position, or of the celestial houses. — 33
- Chap. XIV. On other circles likewise, such as those of declination and of latitude; where also on the ascension and the longitude of the stars. — 37
- Chap. XV. On the threefold position of the sphere: right, oblique, parallel. — 41
- Chap. XVI. On the zones, and accordingly on the quarters of the winds, marked out by the parallel circles of the sphere. — 44
- Chap. XVII. On the climes, and on the variety among the inhabitants of the Earth on account of the parallels. — 48
- Chap. XVIII. On twilights, which are seen at the horizon in any position of the sphere. — 51

- Chap. XIX. On the refractions of the rays of the stars, which occur most of all at the horizon. — 54
- Chap. XX. On the horizontal rising and setting of the stars. — 56
- Chap. XXI. On the heliacal rising and setting of the stars. — 59
- Chap. XXII. On the parts of time (whose measure is the first motion, marked out by the revolution of the sphere), and first on the day. — 61
- Chap. XXIII. On the hour. — 64
- Chap. XXIV. On the week. — 66
- Chap. XXV. On the month. — 68
- Chap. XXVI. On the year. — 71
- Chap. XXVII. On the epochs of time. — 75

LIBER SECVNDVS.

Book Two.

De Doctrina Theorica.

On the Doctrine of the Theories.

- Chap. I. On the various phenomena that gave rise to the theory of the second movables [fecundorum Mobilium]. — 80
- Chap. II. Various kinds of hypotheses for saving, or explaining, phenomena of this sort. — 84
- Chap. III. The Ptolemaic, or common, hypothesis, which works by eccentrics and epicycles. — 88
- Chap. IV. On the theory of the Sun. — 94
- Chap. V. On the theory of the Moon. — 97
- Chap. VI. On the theory of the three superior planets, namely Saturn, Jupiter and Mars. — 104
- Chap. VII. On the theory of the two inferior planets, namely Venus and Mercury. — 108
- Chap. VIII. On the theory of the firmament, and of one crystalline sphere, or a second, built above it. — 111
- Chap. IX. Why the planets appear now larger, now smaller. — 117
- Chap. X. Why they are now fast, now slow. — 119
- Chap. XI. Why they are now direct, now retrograde, now stationary. — 121
- Chap. XII. What parallax is, on account of which the planets are judged higher or lower. — 125
- Chap. XIII. What, accordingly, the distance of each of them, and also of the fixed stars, from the Earth is; and so what the order of the heavens is. — 127
- Chap. XIV. What, likewise, the true size of the same bodies and of the fixed stars is (but with their apparent diameters taken into account at the same time). — 131
- Chap. XV. What the aspects of the planets are. — 134

- Chap. XVI. On the various phases of the Moon, according to the variety of its aspects, or configurations, with the Sun. — 137
- Chap. XVII. On the eclipse of the Moon. — 143
- Chap. XVIII. On the eclipse of the Sun. — 150

LIBER TERTIVS.

Book Three.

De ſpecialibus Copernici, & Tychonis Syſtematibus.

On the Particular Systems of Copernicus and Tycho.

- Chap. I. Whom Copernicus imitated in devising his system. — 155
- Chap. II. In what position and order, accordingly, he placed the Earth and the stars. — 158
- Chap. III. What kind of threefold motion he attributed to the Earth. — 163
- Chap. IV. Why he did not think the senses were to be trusted concerning the motion or rest of the Earth, or of the stars. — 167
- Chap. V. What reasons seemed more fitting for establishing the daily motion of the Earth. — 169
- Chap. VI. What reasons seemed more fitting for establishing the annual motion. — 173
- Chap. VII. What reasons, finally, seemed more fitting for introducing the third motion. — 180
- Chap. VIII. What the Copernicans reply to the objections usually raised from astronomy. — 188
- Chap. IX. What they reply to those from physics. — 193
- Chap. X. What they reply to those from Holy Scripture. — 202
- Chap. XI. What they determine about the distance of the stars from the Earth, and about their size. — 205
- Chap. XII. What kind of world system it is that Tycho Brahe introduced. — 209
- Chap. XIII. By what reasons he was led to devise it. — 212
- Chap. XIV. How it is defended by Tycho's followers. — 214
- Chap. XV. What, according to him, the distance and the size of the stars are. — 219
- Inaugural Oration. — 223

ERRATA.

Errata.

Page 42: in the second figure read *obliquus*; in the third read *parallelus*. Page 49, line 23: add at the end *leli de-*. Page 67, line 2: read *æquicrura*; antepenultimate line, *velint*. Page 78, line 1: *Ptolemæus*. Page 106, line 24: *vt arcus*. Page 114, line 5: *Prætereo*; line 16: *Excentricum*. Page 137, penultimate line: *à nobis*. Page 144: supply *Luminoſum æquale*, which was cut away from the type

by some chance or other. Page 67, line 20: *ac ipſe*. Page 178, line 22: for *quæ* read *ea*. Page 226, line 5: *que*. Page 239, line 26: *præſcriptarum*.

SVMMA PRIVILEGII.

Summary of the Privilege.

In accordance with the privilege granted by the Most Christian King, it is provided that no one in the whole kingdom may print Pierre Gassendi's *Institutio astronomica*, etc., or sell copies printed elsewhere, except Louis de Heuqueville, bookseller of Paris; and this for ten years, under the customary penalties. Given at Paris, 1642 April 8.

Signed, Ceberet.

Issued from the press, 1647 July 20.

INSTITVTIONIS ASTRONOMICÆ PROOEMIALIA.

Preliminaries to the Astronomical Instruction.

What Plato called astronomy, most of the other ancients called astrology as well. But ever since the Chaldeans brought their trifles into this doctrine, the name astrology has generally been given to genethlialogy [Genethliacæ] (which is also generally called judicial astrology [Iudiciaria]), while the name astronomy has been given to the discipline occupied with contemplating and measuring the motion, distance, order, size and light of the stars, and the other like things connected with them.

Wonder gave it its origin: namely, at the time when people observed in the stars, besides their splendour, variety, multitude and greatness, a motion so constant, so regular, so unceasingly bringing about the alternations of day and night, and of summer and winter.

Astronomy is commended above all by the dignity of its subject matter, which is nothing other than the widest and noblest region of the whole world: the celestial and starry region, that is — the region which, so the wiser sort say, people both possess eyes and carry their faces upright in order to contemplate.

The Babylonians contend over its invention and its antiquity on account of Belus as its author; the Egyptians, on account of Mercury; the Moors, on account of Atlas and Hercules; the Greeks, on account of Jupiter, Orpheus and Atreus; the Scythians, on account of Prometheus; and so on.

Of the peoples whose observations survive, the Babylonians are the most ancient: Ptolemy, indeed, records several eclipses observed by them a little more than 700 years before Christ. What they relate about still earlier times is either proved by no record or smacks of fable.

But the observations of the things that appear in the stars (which are therefore called phenomena [Phænomena]) are the true foundations of all astronomy, insofar as, once a fair number of observations have been made and compared, hypotheses are devised, or circles and orbs are supposed, according to which it may be probable that the stars move, to this end: that the things that are observed should appear just as they are observed.

I pass over, moreover, the fact that from time to time what they call Astronomical Tables are compiled: that is, tables [Abacos] that express in numbers, or in arithmetical notation, the times that the stars spend in completing their circuits according to the hypotheses assumed.

I pass over, too, the fact that from the tables are prepared ephemerides [Ephemeridas], or day-books [Diaria], which — once fixed starting points of the motions and of the times have been established — show in what places in the heaven the Sun, the Moon and the other stars stand on each single day, and how they are configured with one another.

Further, since astronomy is the principal part of cosmography, or the delineation of the world, and nothing can therefore be fittingly said or understood about the heaven and the stars unless a general system of the world is held before the eyes, a diagram is to be set here below, to represent the arrangement of the parts of the world as it is commonly both conceived and taught.

In it, the innermost little circle that you see represents the globe of Earth and Water; the two circles that follow represent Air and Fire (which are the two upper elements).

Diagram. A full-page framed woodcut of the world system as commonly taught: a set of concentric rings, open at the top where the heading stands, drawn round a central globe. At the centre a globe of land and water is surrounded by a band of clouds (air) and a band of flames (fire). Outside these come the rings of the seven planetary heavens, each labelled along its arc with the planet's sign between dotted leaders; then the sphere of the fixed stars, with stars drawn in a band among the outer rings; then two crystalline heavens and the first moving sphere. Labels, from the top inward:

- Head of the frame (roman capitals): COELVM EMPYREVM IMMOBILE. — the motionless empyrean heaven
- Outermost ring (roman capitals): PRIMVM MOBILE. — the primum mobile
- Next ring: crystallinum alterum. — the second crystalline heaven
- Next ring: crystallinum vnum — the first crystalline heaven
- Next ring: Aplanes seu Firmamentum — the sphere of the fixed stars [Aplanes], or firmament
- coelum ♄ Saturni. — the heaven of Saturn
- coelum ♃ Iouis. — the heaven of Jupiter
- coelum ♂ martis. — the heaven of Mars
- coelun ☉ solis. — the heaven of the Sun
- coelum ♀ veneris. — the heaven of Venus
- coelum ☿ [?] — the heaven of Mercury (the name, set along a tightly curving ring, is not securely read)
- coelum ☾ lunæ. — the heaven of the Moon

The eleven circles that follow display the eleven movable heavens. Seven of them are proper to the planets, and are called those of the Moon, Mercury, Venus, the Sun, Mars and Saturn. One is the heaven of the fixed stars [Stellarum

Inerrantium], which is therefore called the Aplanes and the firmament. Two are the crystalline heavens, so called because, being ἄναστροι [Greek: ἄναστροι (anastroi, "starless")] — devoid of stars — they are transparent in a special way. And finally there is one supreme heaven, itself also starless, which is called the primum mobile.

I say "movable" heavens because the theologians posit a twelfth, and that one immovable: namely the empyrean heaven, as being the seat of the blessed minds [Mentium beatarum]. It is held to be square in form on its outside, because the holy City described in the Apocalypse is said to be laid out foursquare [in quadro].

For keeping the number and order of the heavens in memory, this couplet can help:

> Moon, and Mercury, Venus, and Sun, Mars, Jove, Saturn, Firmament, two Crystallines, Primum, and Empyrean.

But since in the movable heavens a twofold motion is observed in general — one called the first, or diurnal, common to all; the other the second, proper to some or to each one singly; and since for explaining the first there has been devised what they call the material sphere, and for the second what they call the theory of the planets — it follows from this that two parts of astronomy are usually distinguished, one of which is called the doctrine of the sphere [Doctrina Sphærica], the other the theoric [Theorica].

Accordingly we too shall speak briefly about both. And since it is worth the effort to learn the subject first of all according to the commonly received opinion, which supposes a system of the world of the kind described just above, we shall therefore pursue it in two books: in the first of them we shall set out what pertains to the doctrine of the sphere, in the second what pertains to the theoric.

Then, however, because two other systems have by now become very celebrated — one of Copernicus, the other of Brahe, each of which is winning noble supporters — we shall attach a third book to these as a kind of appendix, so that one may also learn what those systems are, and how [?] they are defended by their adherents.

INSTITVTIONIS ASTRONOMICÆ LIBER PRIMVS, SIVE DOCTRINA SPHÆRICA.

Book One of the Astronomical Instruction, or the Doctrine of the Sphere.

CAPVT I.

Chapter 1.

Quid Sphæra ſit, & ex quibus conſtet.

What the sphere is, and what it consists of.

Since, then, we must begin from the doctrine of the sphere, it is to be supposed that by the name of "sphere" is here understood that common instrument — to be shown presently, so far as it can be represented on a plane — which consists of various circles, or armillae [armilliſve], and is pierced through by an axis, with a small globe in the middle. It is commonly used to represent both the machine of the world and the celestial motions, and especially the first, or diurnal, motion.

For first of all, that small globe which is held up in the middle, the Earth in the centre of the machine of the world set there, represents; and the two ends of the axis that passes through it, on which the revolution takes place, represent the two poles, one called the northern [Boreum], the other the southern [Auſtrinum]. On these poles the whole machine of the heavens is turned with the motion that is completed in the space of 24 hours. The Latins call this motion diurnal; the Greeks call it *nychthēmeros* [Greek: νυχθήμερος (nychthēmeros, "of a night and a day")], "night-daily" as it were [quaſi nocti-dialis], because it takes in the space of both day and night.

The sphere, it is true, is not built up from as many orbs as the heavens we described earlier. Yet the whole structure of the heavens can be understood from this simple framework of circles, in that, just as the instrument is moved on the poles of the sphere, so that whole structure is moved by a single sweep on the poles of the world.

That is to say: although the lower heavens perform special motions of their own, by which they withdraw, as it were, towards the east — and do so along the circle that will presently be called the zodiac — they are nevertheless all swept away towards the west by a single impulse from the primum mobile standing above them, and carried round within the same time, namely 24 hours. Hence it also comes about that the stars set in those heavens appear to rise and set daily, or to go and come back; and the motion impressed on them is called the rapt motion [Raptus].

This rapt motion, meanwhile, presupposes that all the heavens must be not only transparent but also contiguous, solid and hard, and that the stars adhere to them, so that, of course, they can be swept along together. Though this is not true in reality, it can nevertheless be admitted as a hypothesis for explaining the motions.

As for the circles of the sphere, they are distinguished as ten in number; and of these, six are called greater (or

Diagram. A full-page woodcut of an armillary sphere on a turned baluster stand with a broad round base. The meridian ring, graduated in degrees with figures in tens, carries the poles; a small globe sits at the centre; the zodiac band crosses obliquely, graduated 10–20–30 along its length; the horizon ring cuts the sphere across the middle. Circle names are cut in the block as fragments where one ring passes behind another; they are given here as they stand, without assembling them.

- POLVS BOREVS (outer ring, upper left): the north pole

- MERIDIAN' (outer ring, top): the meridian
- COLV (lower left of the upper hemisphere) — fragment
- POLARIS / ARCTIC9 (band running up from the left): "polar … arctic" — on the arctic polar circle
- RVS SOLSTI / TIO / RVM (band running from top centre down to the right): fragments, "… of the solstices" — probably of a colure name (not assembled)
- COESTIVVS (band below ARCTIC9) — fragment ending "-æstivus"/"summer" [?] (the first letters are not separated at this size)
- LVR (below COESTIVVS) — fragment
- a vertical run of letters between POLARIS and LVR — not read [?]
- TRO … [?]CVS (left vertical band) — fragments, probably of a tropic's name; the middle letters are hidden
- RV, VS ÆQ, TIO (bands near the centre) — fragments
- ZO / DIA / CVS (the graduated oblique band): the zodiac
- IVI, ÆQ, ALIS (band to the right of centre) — fragments
- TO, TOR· (band at upper right) — fragments
- HORIZON·RATIONALIS (horizon ring): the rational horizon
- TROPIC' and OPIC'N (lower left bands) — fragments of tropic names
- C, H (single letters, lower centre) — fragments
- ANTA / RCTICVS (band at lower right): antarctic
- POLVS AVSTRINVS (outer ring, lower right): the south pole greatest), in that each of them divides the sphere into two equal parts. These are the horizon and the meridian, within which the rest revolve while the two themselves stay unmoved; and besides these the equator, the two colures, and the zodiac, or broader circle, along the middle of which is drawn the line that is also called the ecliptic [Ecliptica linea].

Four, however, are called lesser, in that each of them divides the sphere into two unequal parts: namely the two tropics and the two polar circles. Together with the equator, these are called parallels for the reason that they are everywhere equidistant from one another.

My remark in passing that the zodiac is a broad circle presupposes that the others are to be conceived as indivisible, even though on the sphere they are not found as such, because such circles cannot be made and fitted together. And I add "to be conceived" because, when we look for them in the sky, they are perceived not by the eyes but by the mind alone — the horizon, however, excepted.

There are, indeed, other circles besides these to be understood in the heavens; but they will be discussed later.

It should be noted here that every circle is usually divided into 360 degrees, or equal parts, and each degree is understood to be subdivided into 60 small parts, which are called first minutes [Prima Minuta], or also simply minutes. In the same way each first minute is for the most part understood to be subdivided

into 60, called seconds [Secunda]; each second into 60 thirds [Tertia]; and so on, if need be, into fourths, fifths, and so forth.

In the same way, too, when the day is divided into 24 hours, the hour is usually subdivided into 60 first minutes, each first minute into 60 seconds, each second into 60 thirds, and so on.

CAPVT II.

Chapter 2.

De vocato Cæleſti Globo, quatenus idem cum Sphæra eſt.

On the so-called celestial globe, insofar as it is the same as the sphere.

The circles of the sphere just mentioned are usually represented also on that which commonly passes through everyone's hands and is called the celestial globe [Globus Cęleſtis]. It is, indeed, the same as the sphere, provided that whatever empty spaces there are in the sphere between its movable circles are understood to be filled in and rounded off, and marked with those figures of the stars [Stellarum Imaginibus].

That is to say, the surface of the globe, for its part, presents to us the face of the firmament, or the view of the fixed stars, which were long ago grouped into certain figures or images. These they call [Greek: ἀστε[?]σμοὺς (one sort before σ not settled between a ρι ligature and a plain ι; the sentence pairs the word with "constellations")], or constellations, and celestial signs; and because Aratus, after Eudoxus, described them, there is no lack of people who call the celestial globe the Aratean sphere [Aratęam Sphęram].

Moreover, right from ancient times 48 constellations were distinguished, comprising the stars visible in Greece and in the whole part of the world then known. Of these, 12 are drawn in the zodiac, 21 to the north of the zodiac, and 15 to its south; and they are usually expressed in these verses:

> *In the sign-bearer are twice six celestial signs; and they are Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpius, the Archer [Arcitenens], the Goat [Caper], the Water-jar [Amphora], Pisces. To the north, thrice seven are seen: Ursa Minor, Major, the Guardian [Cuſtos], the Dragon [Draco], the Jewel [Gemma], and the one fallen on his knee [Genúque Prolapſus], the Lyre [Lyra], the Swan [Olor], Cepheus, and Cassiopeia, Perseus, Andromeda [Andromede], the Triangle [Deltotum], the Charioteer [Auriga], the Horse [Caballus], the Horse's Muzzle [Rictus Equi], the Dolphin [Delphin], the Dart [Telum], then the Eagle [Aquila], the Serpent-bearer [Anguifer], the Serpent [Anguis]. Finally, thrice five are noted, turned towards the south: the Whale [Cetus], and Eridanus, the Hare [Lepus], and stormy Orion, Sirius [?], and Procyon, the ship Argo [Argo ratis], the Hydra [Hydraque], the Bowl [Crater], the Raven [Coruus], the Centaur [Centaurus], the Wolf [Lupus], the Altar [Ara], the Crown [Coronàque], the Fish [Piſcis].*

In more recent times, however, after sailing to the south had revealed stars that had been invisible to the ancients, twelve further constellations have been distinguished, which are contained in this distich:

Phoenix, the Crane [Grus], the Indian [Indus], the Swordfish [Xiphias],
the Peacock [Pauo], the Goose [Anſer], and the Water-snake [Hydrus],
the Sparrow [Paſſer], the Footless Bird [Apus], the Triangle [Triquetrum],
the Fly [Muſca], and the Chameleon [Chamæque-leon].

I pass over the fact that certain smaller constellations were marked out within those larger ones, such as the Pleiades and the Hyades in Taurus; the Manger [Prę̨ſepe] and the Asses [Aſellos] in Cancer; the She-goat [Capellam] and the Kids [Hædos] in Auriga; and so on.

I also pass over the fact that some stars, left as it were in the spaces between the constellations themselves, are therefore called unformed [Informeis], because they are seen outside the forms, or images, to which the rest belong.

Finally, I pass over the fact that when, long ago, the most conspicuous stars were numbered at one thousand and twenty-two, the chief of them were said to be of the first magnitude, such as Sirius (called the Greater Dog [Canis major] and Canicula), and likewise Lyra, Capella, Arcturus and others; those somewhat smaller, of the second, such as the star called Polaris at the very end of the tail of Ursa Minor, and those in Ursa Major that are called the Septentriones; those somewhat smaller still, of the third; and again of the fourth, fifth and sixth, with the addition of some also which they called nebulous [Nebuloſas] and obscure [Obſcuras].

Shall I note that the nebulous stars, such as the so-called Manger of Cancer [Præſepe Cancri], have been found with the telescope, or optical tube, to be nothing other than certain heaps of very minute stars, whose little lights, joined together, produce the appearance of a whiteness and, as it were, of a small cloud?

Or that it has also been found that the Milky circle [Lacteum circulum] drawn on the globe — which the ancients held to be an eleventh circle, and one broad like the zodiac — is nothing other than a kind of fabric of such small clouds, or an indescribable heap of very minute little stars, such as Democritus, as Plutarch reports, had conjectured long ago?

CAP. III.

Chapter 3.

De repræſentata in medio Sphæræ Terra.

On the Earth, as represented in the middle of the sphere.

Now, since the small globe in the middle of the sphere has been said to represent the Earth, it must therefore be understood first of all that the Earth is spherical in form. For its mountains and valleys do no more harm to its

roundness (considering, that is, the size of its circumference) than the graininess of its skin does to an orange [malo arantio].

The natural philosophers [Phyſici] do indeed prove this roundness from the coming together of all its parts, which press equally towards the centre; but the astronomers demonstrate it conclusively from the fact that, for those travelling north or south, different parts of the sky are uncovered in one direction and hidden in the other, and the visible pole becomes higher in one direction and lower in the other.

and from the fact that, according as each person is farther towards the east or the west, he sees the stars rise and set earlier or later; and so, while the Moon, for example, is undergoing an eclipse, the more easterly observer counts more hours from noon or midnight, and the more westerly, fewer.

Under the name of the terrestrial globe [Globi Terræ], however, water must be understood as included as well, insofar as the parts of water and of earth tend together towards the same centre, and the surface of the sea is so continuous with that of the land that the same things just mentioned happen to those sailing north or south, and again to those situated towards the east or the west. Indeed, even this proves that the surface of the sea is not flat: for those setting out from port, the land is gradually hidden (by the hump of the sea, that is) until at last none of it appears. Not to mention that the shadow cast by the surface of the earth and sea on the disc of the Moon when it suffers an eclipse is likewise circular.

Next, that the Earth is at the centre of the world (and therefore that its centre is the same as the centre of the world) is proved by the natural philosophers from the withdrawal of all heavy bodies from the surface of the world and their flowing together into its centre — moving away from which is ascending — and in which, accordingly, the Earth is held as if balanced by its own weights. By the astronomers it is proved from the fact that otherwise the world would not appear divided into two hemispheres, and so more or fewer than six signs of the zodiac would be seen above the Earth; and that eclipses of the Moon would not occur at its diametrical opposition to the Sun (the Earth, that is, not intercepting), and other similar things.

Furthermore, although the Earth contains in its circumference 8,000 and nearly 800 moderate leagues (that is, leagues of the kind made up of three Italian miles), nevertheless, when it is compared with the firmament [Firmamentum], it is as it were a point. This is proved inasmuch as, wherever the eye is on the Earth, it sees half of the heaven, and from wherever it looks at the stars, it finds them neither larger nor smaller. Indeed, it can even be called a point when compared with the heaven of the Sun; for we see the shadows of the Sun move around the centres of instruments and of sundials no less regularly than around the centre of the Earth — exactly as if there were nothing between the Earth's surface and its centre.

Finally, that the Earth, set in the middle of the world, is at rest is usually proved from the fact that it moves neither with a straight motion — because

it would leave the very centre and so would ascend, which is contrary to its heaviness — nor with a circular motion, because it cannot move either about its own axis or about another's. For if it moved about its own axis towards the east, everything existing in the air, such as clouds and birds, would appear to be carried towards the west; and moreover nothing would fall along the perpendicular — contrary to what is observed to happen. If it moved about another's axis, the altitude of the pole would vary for us who are at rest on the Earth's surface; and this never happens.

CAP. IV.

Chapter 4.

De Axe, & Polis, qui dicuntur Mundi.

On the axis and the poles, which are called "of the world".

With these things set out about the little globe that represents the Earth and the water, it would seem that something should be said about the interval that lies between it and the framework of circles, as though that interval represented the air and the fire. But since either the air is nothing other than a texture of exhalations or corpuscles issuing from the earth and water and rising scarcely to the height of a few miles, or there exists below the Moon no such fire — a fire whose thickness would be more than 70,000 leagues — but rather, after the thick and earthy air, there follows all the way up to the Moon the purest aether, or, as they now say, aetherial air; there is therefore no need for us to invent anything here about the air or that fire.

Rather, what must be noted concerns the axis by which that little globe is supported in the middle of this interval. The Earth, indeed, is not supported in the same way by any visible axis terminating at the heaven itself; but nevertheless an indivisible line is understood, passing through its centre and that of the world, which, extended in each direction as far as the primum mobile, ends in those two points that they call the poles, or hinges [Cardines], of the world; so that the poles of the world are, accordingly, nothing other than the ends of the axis.

We have already said that one of these poles is the Boreal, or Septentrional, the other the Austral, or Meridional. The former, moreover, is usually also called Arctic, from its vici- nity to the twin Bears, which the Greeks call [Greek: [?]ρκτος (arktos, "bear")] (for we have also already said that, from its nearness to this pole, the star situated at the tip of the tail of Ursa Minor is in turn called Polaris; it is distant from the pole, at the present time, 2⅔°). The latter, on the other hand, is called Antarctic, because it lies opposite the Arctic.

They are called the poles, or hinges, of the world because the principal part of the world, namely the machine of the heavens, turns daily upon them — for [Greek: πολεῖν (polein, "to turn")] means "to turn" — and completes an entire revolution from east to west. It is known, too, that in Latin the poles

were called *Vertices*, from *vertendo* ("turning"); and that the Poet accordingly expressed in this way the Arctic pole, visible to us, and the Antarctic, invisible:

This pole [Vertex] stands always high above us; but that one black Styx and the deep shades see beneath their feet.

Moreover, they are called poles of the world (and also of the primum mobile) to distinguish them from the poles of the zodiac, about which, namely, take place the proper revolutions of the second movables, or lower heavens (and these proceed obliquely from west to east), but above all that of the Sun itself. And because the Sun travels continually along the line called the ecliptic, the poles of the ecliptic are therefore both the principal ones and the more frequently named.

Hence, too, the axis of the world is the name given to the axis that terminates at the poles of the world and about which the whole machine of the heavens is understood to turn with that daily motion; whereas the axis of the zodiac is the one which, also understood to be passed through the Earth, terminates at the lower heavens, and about which we conceive the proper revolution of each of them to take place. Hence, also, in certain spheres there are usually enclosed both the cir- cles and portions of axes by which the heavens and the axes — chiefly those of the Sun and the Moon — can to some extent be represented.

Although any axis whatever is conceived as passing through the middle of the Earth, nevertheless, since none except the axis of the world is fixed, this axis alone, where it emerges, as it were, from the Earth in each direction, marks two points on the Earth. Because these lie directly beneath the celestial poles, they too are called poles (namely, poles of the Earth itself); and the one is likewise called Arctic, or Boreal, the other Antarctic, or Austral.

CAP. V.

Chapter 5.

De Horizonte.

On the horizon.

As for the circles, the one called the horizon [Horizon] is the circle that is outermost in the sphere and surrounds the others. In the world it represents that circle which, while we are on a plain and cast our eyes around us, appears to us as a kind of joining of the heaven and the earth. For this reason it is called in Greek [Greek: ὁρίζων (horizōn, "bounding")], and in Latin *Finiens* and *Finitor* ("the one that bounds"), because it bounds whatever we see from the earth; it also separates the part of the heaven that is seen from the part that is not seen, and distinguishes the two hemispheres, which they call the upper and the lower.

It is the circle above which the stars, as they emerge, are said to rise, and below which, as they sink, they are said to set.

Although the horizon is immovable with respect to each particular place on the earth, yet, conceived universally, it is changeable, inasmuch as when we change our place on the earth, we also change our horizon.

The horizon of the sphere, however, can represent this variation. For although the horizon is not itself moved around the rest of the sphere, the rest of the sphere is nevertheless movable within it; and it makes no difference which of the two has the motion for the same change to appear to be produced.

This change, moreover, is produced by the convexity of the earth's surface, and specifically of that portion of it which we look around us at. For even a surface that has been levelled, although it appears plane to the senses, is in reality slightly curved downward; and therefore, as we move, something of it is lost on one side and something is made up on the opposite side.

What I am saying — that the surface of the Earth, even when levelled, is not plane but curved downward — is understood even from the sea itself. In arranging itself spontaneously to the level, the sea at the same time arranges itself into a round figure, however plane, or straight, that surface may appear to the senses over a small space, and however much it is for that reason commonly used for levelling, or for testing whether some area is plane.

From this it is understood, in passing, that no two plumb-lines are in reality parallel; and therefore that not even two neighbouring walls erected by the plumb-line are parallel, however much they may appear so to the senses. For since all plumb-lines fall onto a convex surface, they would meet at the centre if they were understood to be produced — as can be clearly understood even from the figure placed beside the text.

Diagram. A circle with five straight lines drawn from its centre, fanning upward; each line crosses the circumference and runs on beyond it. The text cites the figure for its point that plumb-lines falling onto a convex surface would meet at the centre if produced. The block carries no letters.

What would have to be touched on here concerning the right, oblique and parallel horizon will be dealt with later, more conveniently.

It need only be noted here that some distinguish a twofold horizon, the sensible [Senſibilem] and the rational [Rationalem]. The sensible is the one described so far, inasmuch as it appears as a plain; the rational is the one that would appear if, with the earth cut in two and one of its halves made to vanish, one looked around from the centre.

Both can be understood from the figure placed beside the text. In it the inner circle represents the Earth and the outer the heaven; the line passing through the centre represents the rational horizon, and the line that touches the surface the sensible. Both, moreover, are produced as parallels right up to the heaven, so that we may understand that an interval taken in the heaven as great as the semidiameter of the earth will be regarded as virtually a point (the lines, that is, being seen to meet because of the immense distance), and that a star will thus be seen in the same place whether it is viewed from the earth's surface or from its centre.

Diagram. A large circle (the heaven) with a small circle (the Earth) at its centre. A horizontal line through the common centre runs across the large circle; a second horizontal line, parallel to it, touches the top of the small circle and likewise runs to the large circle.

- Above the upper (tangent) line: *horizon sensibilis* — "sensible horizon" [first s of *sensibilis* not separable between round and long s]
- Between the two lines, left of the small circle: *horizon*; right of the small circle: *Rationalis* — together "rational horizon"

CAPVT VI.

Chapter 6.

De Meridiano.

On the meridian.

Another circle in the sphere, within which the others move while it stays unmoved, is the meridian [Meridianus]. It is, namely, the one that cuts the horizon at right angles and supports the ends of the axis, that is, the poles.

In the world it represents the circle that we conceive to pass through the poles of the world and through two points. One of these, standing over the head, is called the vertical point [Verticale], and frequently, by an Arabic word, Zenith; the other, opposite to it beneath the feet, is called Nadir — not to mention that these two points are regarded as poles, as it were, of the horizon.

Dividing the world into two hemispheres, one of which is eastern and the other western, this circle is called the meridian [Meridianus] because, whenever the Sun comes up to it, midday [Meridies] is produced. At that moment the Sun is at equal distances from the points of rising and of setting, so that as much time remains to pass until setting as has passed since rising.

I pass over the fact that, just as the upper part of the meridian divides the daytime into two equal parts, so the lower part cuts the night-time into two equal parts.

Further, the fact that the meridian is unmoved in the sphere does indeed represent the meridian of each particular place, which is itself also invariable. But because, whenever we turn aside either toward the east or toward the west, we are under new and ever new meridians, the meridian of the sphere does not represent many and various meridians, except inasmuch as, by the motion of the rest of the sphere [Sphætæ] [recte: Sphæræ], it becomes [?] the equivalent of many.

I say "toward the east or the west"; for if someone travels directly toward the north or the south, the meridian will always be the same for him.

It is therefore known why, for those who are under the same meridian, midday occurs at the same time, whereas for those who are under a more easterly one it occurs earlier, and for those under a more westerly one, later:

the Sun, of course, reaches the meridian sooner for the former and later for the latter.

Note, moreover, that since the stars ascend right up to the meridian and from it thereafter descend, the greatest altitude of each is for that reason called its meridian altitude [Meridianam]; and the point of the meridian through which a star passes is called, with respect to that star, the middle of the heaven [Medium cæli], just as the point lying directly opposite to it beneath the earth is called the lowest [Imum].

Note also that the elevation, or altitude, of the pole [Eleuationem, ſiue Altitudinem Poli] in any region is nothing other than the arc of the meridian intercepted between the horizon and the raised pole; and its complement up to the zenith, that is, to a quadrant of the circle, is always equal to the altitude of the equator.

Thus, for example, since in this city of Paris the altitude of the pole is 48° 50′, its complement, that is, the altitude of the equator, will be 41° 10′.

CAPVT VII.

Chapter 7.

De Æquatore.

On the equator.

Next, the equator [Æquator], the chief of the movable circles in the sphere, is the circle that stands everywhere at equal distances from each pole of the world.

For this reason it also represents in the heaven that circle which we conceive to be equally distant from each pole,

and to divide the world into two hemispheres, the one northern, the other southern.

It is also called the equinoctial [Æquinoctialis] (the Greeks rather say ἰσημερινὸν [Greek: isēmerinon, "of equal day"], that is, "equidial" [Æquidialem]), because the Sun, cutting it twice a year — that is, about March 20 and September 23 (namely where the beginnings of the signs of Aries and Libra lie) — produces two equinoxes, or makes the nights equal to the days, through its equal stay above and below the horizon. For the equator, cut by the horizon, falls into two parts, one upper and the other lower, which are always equal.

Note in passing that by the name "day" is here understood the Sun's stay above the horizon, and by the name "night" its stay below: that is, what they call twilight, the morning as much as the evening, is usually counted as part of the night.

It must not go unsaid, moreover, that the equator is the chief measure of time [Temporis menſuram], inasmuch as it is chiefly by the equator that the revolution of the primum mobile is gauged. So much so that if the revolution is whole, or of 360° (with a small addition, of which below), its duration is

one day (taking "day" now, of course, in another sense); but if it is only of a twenty-fourth part, or of 15°, its duration is one hour; and so on for the rest.

CAPVT VIII.

Chapter 8.

De Tropicis.

On the tropics.

Of the four circles parallel to the equator, the two that lie nearer on either side in the sphere are the tropics.

The tropics represent in the heaven two circles described by the Sun: one when it has advanced farthest towards the north, the other when it has withdrawn farthest towards the south. And hence also, on account of the τροπὰς [Greek: tropas, "turnings"], the conversions [conuerſiones], they are called τροπικοὶ [Greek: tropikoi, "turners"] — as it were "converters" [Conuerſorij] — because the Sun, once it has been carried from the equator as far as them, goes no farther but returns towards the equator.

The circle towards the north is commonly called the Tropic of Cancer, because the sign of Cancer begins on it; the one towards the south, the Tropic of Capricorn, because the sign of Capricorn begins from it.

The former is moreover called the circle of summer, because summer begins while the Sun is on it; the latter the circle of winter, because winter begins while the Sun is on it — understand this with respect to us, who live towards the north.

The former, furthermore, is usually called the circle of the high solstice [Solſtitij alti], because when the Sun occupies it and stands, with respect to us, at its highest, the solstice of the longest day is produced; the latter the circle of the low solstice [Solſtitij imi], because when the Sun is placed on it, and is indeed for us at its lowest, the solstice of the shortest day is produced.

It is well known, moreover, that the solstice is so called because, while the day (that is, the Sun's stay above the horizon) neither lengthens nor shortens perceptibly, the Sun seems for some days to stand still: that is, neither to advance towards the north or the south, nor to recede perceptibly towards the equator.

The distance of each tropic from the equator, moreover, is 23° 31′: for the Sun can recede from the equator, or decline, by just so much and no more

; and so this same distance is also called the Sun's greatest declination [maxima Solis Declinatio].

And since this very distance is the measure of the obliquity with which the zodiac, or ecliptic line, stands to the equator, it follows that the obliquity of the zodiac, or of the ecliptic, is also said to be 23° 31′.

CAPVT IX.

Chapter 9.

De Polaribus.

On the polar circles.

The other two parallels, which lie farther from the equator on either side, are for this reason called polar (the one northern and Arctic, the other southern and Antarctic): because they are near the poles themselves.

They represent in the heaven two circles which we conceive to stand as far, on either side, from the neighbouring pole as the tropics stand from the equator, that is, by 23° 31′.

This is, namely, because the zodiac, being oblique to the equator, touches the tropics in such a way that its own poles necessarily stand as far from the poles of the equator as the tropics themselves stand from the equator; and besides, we conceive the polar circles to be described by the poles of the zodiac around the poles of the equator, or of the world. That, at least, is how the more recent authors put it.

According to the ancients, the polar circles (or, as they called them simply, the Arctic and the Antarctic) were indeed parallel to the equator. But since innumerable parallels could be understood to be drawn between the equator and either of the poles — some always visible around the raised pole, others always hidden around the depressed pole

; and the rest visible in one part of themselves and hidden in another because the horizon cuts them off — therefore, of the polar circles, the one was held to be the greatest of the always-visible circles, the other the greatest of the always-hidden. And so they varied with the variation of the pole's altitude, as though grazing the horizon with one part of themselves.

On this reckoning, at Paris the polar circles — that is, both the greatest of the always-visible circles around the north pole and the greatest of the always-hidden around the south pole — would each stand 48° 50′ from its own pole.

CAPVT X.

Chapter 10.

De Coluris.

On the colures.

Next come the colures [Coluri], or two of the greater circles among the movable circles of the sphere, which, intersecting each other at right angles at the poles of the world, intersect the other movable circles and divide each of them into four equal parts.

They represent in the heaven two circles which we conceive to intersect one another, and the other circles, in the same way. They are therefore thought to have been called κόλουροι [Greek: kolouroi, "docked-tailed"] — as it were "docked" [mutili] — because they never appear above the horizon either wholly

or uniformly (understand the oblique horizon, that is, in the oblique sphere, of which more will be said later).

Further, the one is called the colure of the equinoxes, the other the colure of the solstices: because the former passes through the equinoctial points, namely the beginnings of Aries and Libra; and

the latter through the solstitial points, namely the beginnings of Cancer and Capricorn.

The colures, moreover, mark out in the zodiac four points, called the cardinal points [puncta Cardinalia]: namely the beginning of Aries, in which, while the Sun is there, night is equal to day and spring begins; the beginning of Cancer, in which, while the Sun is there, the day is longest and summer begins; the beginning of Libra, in which, while the Sun is there, night is again equal to day and autumn begins; and the beginning of Capricorn, in which, while the Sun is there, the day is shortest and winter begins. Those familiar verses refer to this:

These two make the solstice, Cancer, Capricorn; But Aries and Libra make the nights equal to the days.

Note, however, that it is a property peculiar to the colure of the solstices that the poles of the zodiac are marked on it: namely at the two opposite points at which it cuts the polar circles, and which are equally distant from the zodiac on every side.

CAPVT XI.

Chapter 11.

De Zodiaco, & Ecliptica.

On the zodiac and the ecliptic.

The zodiac, finally, is that broad circle, laid over the other movable circles, which, touching the tropics on this side and on that and cutting the equator obliquely, is marked with twelve figures, and is divided along its length by a line down its middle, which is called the ecliptic; and it separates the sphere into a northern and a southern part.

It represents in the heaven a corresponding circle — broad, that is, and oblique, and conducting itself in the same way

with respect to the equator and the tropics; similarly divided by a line called the ecliptic, and marked with 12 asterisms; and similarly dividing the heaven into two hemispheres, the one northern, the other southern.

It is called the zodiac because asterisms of this kind are for the most part depicted in the forms of τῶν ζωδίων [Greek: tōn zōdiōn, "of the little animals"] — of animals. Likewise, because such asterisms are called signs, it is called the sign-bearer [Signifer]; and from the obliquity of its position it is also quite often called the oblique circle.

It is judged to be broad, however, for the following reason. The planets move through it, but they do not all keep the same path: the Sun advances along the middle, namely along the ecliptic line, while the others set out on courses oblique to this line, and because their paths are intersected by it at two opposite places, they turn aside now towards the north, now towards the south — some of them more, others less. It is therefore fitting to give this circle a breadth that takes in these deflections, which amount, that is, to six, seven or eight degrees, more or less, on either side.

But of the motions of the planets we shall have to speak more fully in the theoretical part that follows. Here, because of what remains to be said about the doctrine of the sphere, something must necessarily be said in advance about the motion of the Sun.

Thus, although the Sun, carried off by the primum mobile [Mobili primo], completes a circuit every day from east to west, it nevertheless meanwhile moves back with its own slow motion and heads towards the east (and obliquely, indeed, along the course of the zodiac), in the way that a sailor carried along by a ship can walk with a contrary motion, namely from the prow to the stern.

I call it slow, since the Sun completes only one

degree, approximately, by this motion of its own within one day, or 24 hours; nor does it complete a whole circuit except within a year. Hence, just as an ant, while it is carried round by a wheel and turned completely round a hundred times and more, can itself — I say — meanwhile complete one whole circuit, advancing with an opposite motion: so the Sun, carried round by the primum mobile, is turned towards the west three hundred and sixty-five times, while it meanwhile revolves once towards the east by its own motion.

This, further, is the motion by which a circle — the orbit of the Sun [Orbita Solis] — is described through the middle of the zodiac. They call it the ecliptic line for this reason: that the Moon, crossing it while in conjunction with or in opposition to the Sun, produces an eclipse of itself or of the Sun, as will be explained below.

CAPVT XII.

Chapter 12.

De Signis Zodiaci.

On the signs of the zodiac.

It has already been said above that the signs of the zodiac are twelve in number. Here, then, are the characters by which they are usually represented: Aries ♈, Taurus ♉, Gemini ♊, Cancer ♋, Leo ♌, Virgo ♍, Libra ♎, Scorpio ♏, Sagittarius ♐, Capricorn ♑, Aquarius ♒, Pisces ♓.

It is customary to assign 30° to each sign (although the asterisms themselves are unequal to one another, some shorter, others longer); for that many degrees result when 360 is divided by 12.

The count begins, moreover, from Aries, that is, from the

intersection of the vernal equinox, near which the asterism of Aries stood when astronomy began to be cultivated in Greece, about two thousand years ago.

For although this asterism, because of the slow motion of the firmament (of which more will be said later), has since then already moved back, and has passed almost entirely into the place where the asterism of Taurus was, the first 30° nevertheless always keep the name of Aries, just as the following 30° keep the name of Taurus, although the asterism of Taurus has likewise taken over the place of Gemini; and so for the rest.

It follows from this that, for the sake of distinction, these thirty-degree divisions are called not the asterisms, indeed, but nevertheless the signs, of Aries, Taurus, Gemini, and so on; and they are also called dodecatemories [Dodecatemoria], because they are the twelve parts of the zodiac.

The Sun, or another planet, is said to be in a given sign when it is beneath it, that is, when it is interposed between our eye and that sign. The fixed stars that lie outside the zodiac, however, are said to be in that sign — or rather to be referred to that sign — between which and the nearer pole of the zodiac they happen to lie.

Of these signs, ♈, ♉, ♊, ♋, ♌, ♍ are called northern; ♎, ♏, ♐, ♑, ♒, ♓ southern. But ♑, ♒, ♓, ♈, ♉, ♊ are called ascending; ♋, ♌, ♍, ♎, ♏, ♐ descending.

Again, ♈, ♉, ♊ are called vernal; ♋, ♌, ♍ summer signs; ♎, ♏, ♐ autumnal; ♑, ♒, ♓ winter signs.

The first of each of these triads — ♈, ♋, ♎, ♑ — are called cardinal, because the seasons of the year and its quadrants begin when the Sun enters them; and likewise movable [Mobilia], because a change of qualities then takes place: the middle ones,

♉, ♌, ♏ are called immovable [Immobilia], because the weather is then, as it were, fixed. The last ones — ♊, ♍, ♐, ♓ — are called common [Communia], that is, by comparison with the movable and the immovable signs; and also bicorporeal [Bicorporea], because ♊ and ♓ are plainly double, ♐ consists of a horse and a man, and ♍ carries Spica in her hand.

There are, besides, various other names given to the signs, above all by the astrologers. For (among other things), taking them from ♈ and leaving out three each time, ♈, ♌, ♐ are called the fiery, hot, choleric signs; ♉, ♍, ♑ the earthy, dry, melancholic; ♊, ♎, ♒ the airy, moist, sanguine; ♋, ♏, ♓ the watery, cold, phlegmatic. And so ♈, ♌, ♐ are said to make up the fiery trigon [Trigonum Igneum]; ♉, ♍, ♑ the earthy; ♊, ♎, ♒ the airy; ♋, [?], ♓ the watery.

In the same way they call some signs masculine, others feminine; some human, others brute; some fertile, others barren; some beautiful, others ugly; some diurnal, others nocturnal; some the houses of the planets, others their

exiles [Exſilia]; some the exaltations of the same planets, others their falls [Caſus]; and a good many others of that kind, which there is no need at all to touch on.

It is worth noting that in each month the Sun enters a particular sign: for instance, in March into ♈, in April into ♉, in May into ♊, and so on, until in February it enters ♓.

To know, moreover, on about which day of each month this entry takes place, the following verses may be noted:

Liuor mente latens inſultat honoribus, horret Grandia geſta, horrens inſigni laude notatos.

Envy, lurking in the mind, assails honours; it shudders at Great deeds, shuddering at those marked out by signal praise.

That is, if you thus assign these 12 words to the 12 months

so that the first corresponds to March, the second to April, the third to May, and the rest to the rest in order; and if, noting what number in the alphabet the first letter of each word is, you subtract that many units from 30, the remaining number will indicate the day of the entry into the sign.

For example, since the word *Liuor* corresponds to March, and its first letter, L, is the tenth in the alphabet, subtract 10 from 30, and the remaining 20 will indicate that the Sun enters the sign ♈ on the 20th day of March. By the same reasoning, the letter M of the second word, which corresponds to April, will show, with 11 subtracted from 30, that the Sun enters ♉ on April 19. And in just the same way the letter N of the last word, which corresponds to February, will suggest, with 12 subtracted from 30, that the Sun enters ♓ on February 18; and so for the rest.

If, moreover, it is asked in about which degree of the zodiac the Sun is on any given day of any month, nothing else is needed but to add to the given day the number designated by the letter.

For if the resulting number exceeds 30, the excess (with one added) will indicate the degree of the sign which the Sun enters in that month. But if it falls short, the number itself will indicate the degree of that sign which the Sun entered back in the preceding month.

For example, if it is asked where the Sun is on September 28: to 28 add 7, on account of the letter G of the word *Grandia*, which corresponds to September and is the seventh in the alphabet. That will give 35; subtract 30, and the excess, 5, with one added — that is, 6 — will indicate that the Sun is in the 6th degree of ♎, which the Sun enters in that month. And, if it is asked where

the Sun is on the 12th day of the same month: to 12 add 7 again, and 19 will result; this number will indicate that the Sun is in the 19th degree of ♏, which it entered back in the previous month.

CAPVT XIII.

Chapter 13.

De aliis quibuſdam in Sphæra intellectis circulis, vt qui dicuntur Verticales, Altitudinis, Diſtantiæ, Poſitionis, ſeu Domorum cæleſtium.

On certain other circles conceived in the sphere, such as those called verticals, and circles of altitude, of distance, of position, or of the celestial houses.

Besides the circles described so far, other circles can be conceived in the sphere, or celestial globe (and so also in the heaven), which astronomers mention frequently — so much so, therefore, that some of the principal ones among them must not be passed over in silence.

Vertical circles, then, are those that pass through the zenith, or vertical point, and through the nadir opposite it, and that therefore cut the horizon at right angles. These circles are usually called, by an Arabic word, azimuths [Azimutha].

Although innumerable circles of this kind can cut the horizon, according as one moves away from the meridian (which is counted as one of the verticals) towards the east or the west, the one that passes through the intersections of the horizon and the equator is nevertheless held to be the prime vertical [Primarius tamen Verticalis].

Circles of altitude are those taken above the horizon and parallel to the horizon itself; they decrease gradually, that is, they grow ever smaller and smaller, until they end in the vertical point. These too are usually called, by an Arabic word, almucantars [Almicantarath].

It is customary to represent both these kinds of circle on the instruments themselves which they call astrolabes, or planispheres; and they can also be understood from the figure set out here below, which represents half the sphere (as far as it can be viewed in a plane). Thus AB is the horizon; C, the zenith; D, the nadir; CADB, the meridian. The other circles, drawn from the zenith to the nadir through every tenth degree of the horizon, are the verticals themselves, and among them CED is the prime vertical; but FG, HI, and the others parallel to the horizon and drawn through every tenth degree of the meridian, are circles of altitude.

Diagram. A woodcut of the sphere projected on a plane: a circle with C at the top and D at the foot. A horizontal diameter runs from A on the left rim to B on the right rim, with E at its centre, marking the horizon. A family of curved arcs runs from C to D, all meeting at both points — the vertical circles, the straight central one being CED. Above AB a series of arcs crosses the circle parallel to the horizon, growing shorter towards C — the circles of altitude, two of which are lettered FG and HI. A straight line runs from K on the upper-left rim down to L on the lower-right rim, passing two small star-marks lettered M and N.

- C (top of the circle): zenith
- D (foot of the circle): nadir
- A (left end of the horizontal diameter): end of the horizon

- B (right end of the horizontal diameter): end of the horizon
- E (centre, on the horizontal diameter): on the prime vertical CED
- F (left rim, above A): end of the circle of altitude FG
- G (right rim, above B): end of the circle of altitude FG
- H (left rim, above F): end of the circle of altitude HI
- I (right rim, above G): end of the circle of altitude HI
- K (left rim, above H): upper end of the straight line KL
- L (right rim, below B): lower end of the straight line KL
- M (star-mark on KL, upper left of centre): not keyed in the text on this page
- N (star-mark on KL, right of centre, above AB): not keyed in the text on this page

Circles of distance [Diſtantiæ Circuli] is the name given to those that, being among the great circles [maioribus], pass through two stars, of which, therefore, the mutual distance is nothing other than the arc of some circle of this kind intercepted between them.

We can take as such a circle, in the figure given above, the great circle KL, passing through M, the star of Pollux, and N, Spica. The arc MN, that is, which is of 90¾ degrees [90. graduum, cum dodrante], is itself the distance of these stars.

Circles of position [Poſitionis], or of the celestial houses [Domorum cæleſtium], is the name they give both to the horizon and the meridian and to four other circles, which intersect one another, and the horizon and meridian themselves, at the common sections of that same meridian and horizon. And since there are six of them, just as they divide the whole sphere, so they distribute the entire heaven into twelve parts, which they call the celestial houses [Domos cæleſteis]; six of these are below the horizon, six above.

The first is reckoned to be the one that lies immediately below the horizon towards the rising, and it is called both the Horoscope [Horoſcopus] and the house of Life. The next one, lower down, is called the house of Riches; the third, following on, the house of Brothers; the fourth, at the lowest point of the heaven [in imo cæli], the house of Parents; and the rest in order, as they are designated in these two verses:

Vita, Lucrum, Fratres, Genitor, Natique, Valetud', Vxor, Mors, Pietas, & Munia, Amici, Inimici.

Life, Gain, Brothers, Father, and Children, Health, Wife, Death, Piety, and Duties, Friends, Enemies.

It should be noted, moreover, that these circles of position, or of the houses, divide into equal parts — according to some, the equator; according to others, the zodiac; according to others again, the prime vertical.

The matter can be understood from the figure set beside it, in which, representing the eastern hemisphere, AB is the horizon; CADB, the meridian; AEB, AFB, AGB,

AHB, the circles of position [Poſitionum circuli]; IK, either the equator or the ecliptic; CD, the prime vertical. The order of the houses is marked — below the horizon, I, II, III; above it, X, XI, XII — since the number and sequence of the remaining houses too must be understood in the western hemisphere.

Diagram. A woodcut of the eastern hemisphere projected on a plane, showing the circles of position and six of the twelve houses. A circle has C at its top and D at its foot, joined by a straight vertical line; a straight horizontal diameter runs from A on the left rim to B on the right. Four further arcs run from A to B, two bowing above the diameter and two below, and cross the vertical at E and F above and at G and H below. A straight line runs from I on the upper-left rim through the centre to K on the lower-right rim. Left of the vertical, the six bands between C, E, F, the diameter, G, H and D carry the house numbers X, XI, XII above the diameter and I, II, III below it.

- C (top of the circle): upper end of the prime vertical CD; on the meridian CADB
- D (foot of the circle): lower end of the prime vertical CD; on the meridian CADB
- A (left end of the horizontal diameter): end of the horizon AB, where the circles of position meet
- B (right end of the horizontal diameter): end of the horizon AB, where the circles of position meet
- E (on the vertical, highest of the four crossings): on the circle of position AEB
- F (on the vertical, below E): on the circle of position AFB
- G (on the vertical, first crossing below the diameter): on the circle of position AGB
- H (on the vertical, below G): on the circle of position AHB
- I (upper-left rim, outside the circle): end of IK, the equator or the ecliptic
- K (lower-right rim): end of IK, the equator or the ecliptic
- X (band between C and E): house X
- XI (band between E and F): house XI
- XII (band between F and the horizon): house XII
- I (band between the horizon and G): house I
- II (band between G and H): house II
- III (band between H and D): house III

I pass over the fact that some prefer the circles of position to intersect not where has been said, but at the poles of the world; in that case the horizon is rejected and a fifth circle is used alongside the meridian. Others prefer them to intersect at the poles of the zodiac; in that case the meridian too is rejected and a sixth is used — so that there are always twelve houses.

CAPVT XIV.

Chapter 14.

De Circulis itidem alijs, vt Declinationis, ac Latitudinis: vbi & de Aſcenſione, ac Longitudine Siderum.

On other circles likewise, such as those of declination and of latitude; where also on the ascension and longitude of the stars.

Especially necessary to know, however, are the circles called circles of declination [Declinationis] and of latitude [Latitudinis].

The circles of declination are those which, drawn through the poles of the world, cut the equator at right angles. For since the declination of the stars is reckoned from the equator, proceeding towards one or the other pole of the world, it is evident that the declination of any star, or of any other point of the heaven, is nothing other than the arc of any one of these circles that is intercepted between the equator and that star or other point.

It is clear, moreover, that declination is accordingly of two kinds: one northern [Borealem], the other southern [Auſtralem], according, that is, as that point or star lies to the north or to the south of the equator.

So in the figure set below: since AB is the equator, C the north pole of the world and D the south pole, CADB the solstitial colure [colurus Solſtitiorum] and CED the equinoctial colure [Colurus Æquinoctiorum], both the colures themselves and the circles CFD, CGD, CHD, CID will be circles of declination. The declination of the star K (a northern one, that is) will be the arc HK; that of the star L (a southern one) the arc IL. In the same way the declination of the solstitial points M and N will be, the northern, BM, and the southern, AN.

Diagram. A woodcut of the sphere projected on a plane, showing circles of declination and, dotted, a second family of circles together with a dotted line carrying the signs of the zodiac. A circle has C at its top and D at its foot, joined by a straight vertical line; a straight horizontal diameter runs from A on the left rim to B on the right. Solid arcs run from C to D on either side of the vertical and cross the diameter at F and G on the left and at H and I on the right; E stands at the centre, just above the diameter. O stands outside the rim at upper left and P at lower right, and several dotted arcs run from O to P; a star-mark K lies on one of them, upper right of C, and a star-mark L on another, lower right. A dotted straight line runs from N on the lower-left rim, past the centre just above E, to M near the upper-right rim; along it stand, from left to right, the signs ♑, ♒, ♓, ♈, ♉, ♊, with the letters Q, R, S, T and V between them, and beyond M at the rim the sign ♋. A small dark triangular mark stands on the right rim above it.

- C (top of the circle): north pole of the world; on the solstitial colure CADB and the equinoctial colure CED
- D (foot of the circle): south pole of the world
- A (left end of the horizontal diameter): end of the equator AB
- B (right end of the horizontal diameter): end of the equator AB; EB is the right ascension of the beginning of Cancer, M

- E (centre, just above the diameter): on the equinoctial colure CED; the right ascensions are measured from it (EH, EI, EB)
- F (on the diameter, left): on the circle of declination CFD
- G (on the diameter, left of centre): on the circle of declination CGD
- H (below the diameter, right of centre): on the circle of declination CHD; HK is the declination of the star K, EH its right ascension
- I (on the diameter, right): on the circle of declination CID; IL is the declination of the star L, EI its right ascension
- K (star-mark, upper right): a star of northern declination
- L (star-mark, lower right): a star of southern declination
- M (upper right, on the dotted line): solstitial point, beginning of Cancer; its northern declination is BM
- N (lower-left rim, at the end of the dotted line): solstitial point; its southern declination is AN
- O (outside the rim, upper left): end of the dotted arcs; not keyed in the text on this page
- P (below the rim, lower right): end of the dotted arcs; not keyed in the text on this page
- Q, R (on the dotted line, left of centre): not keyed in the text on this page
- S (below the dotted line, left of centre): not keyed in the text on this page
- T, V (on the dotted line, right of centre): not keyed in the text on this page
- ♑, ♒, ♓, ♈, ♉, ♊ (along the dotted line, left to right): signs of the zodiac
- ♋ (at the rim beyond M): the sign ♋, its sort shaped like the figures 6 and 9 set close

It should be noted, however, that right ascension [Aſcenſionem rectam] is coupled with declination. This is the name they give to the arc of the equator intercepted from the beginning of ♈ up to the point at which the designated circle of declination cuts the equator — inasmuch as that point rises, or ascends, together with the designated point of the heaven, or star, in the right horizon. Which horizon is right and which oblique will be understood more fully presently, from the following chapter.

So the right ascension of the star K will be the arc of the equator EH; of the star L, the arc EI; of the beginning of Cancer, M, the arc EB — that is, a quadrant, or 90 degrees; of the beginning of Capricorn

the arc EB, together with the whole of the remaining hemisphere as far as A — that is, three quarters of the circle [dodrans], or 270 degrees.

It is called right ascension [Aſcenſio Recta] because, where the horizon is oblique, the ascension is oblique as well: the same point of the equator no longer rises together with the designated point of the heaven, or star, but some other point, earlier or later. From this it follows that the arc of the equator intercepted between these two points is called the ascensional difference [Aſcenſionalis differentia].

So in this city, for example, the ascensional difference of the beginnings of ♋ and ♎ is 30 degrees. And since the beginning of ♋ rises later, and the beginning of ♎ earlier, than the point of right ascension, it follows that at Paris the oblique ascension of the beginning of ♋ is 120 degrees, and that of the beginning of ♎ 240. The same is to be understood, in proportion, of the stars.

The circles of latitude [Latitudinis circuli] are those which, drawn through the poles of the zodiac, or of the ecliptic, cut the ecliptic at right angles. For since the latitude of the stars is reckoned from the ecliptic, it is evident that latitude is nothing other than the arc of any one of these circles that is intercepted between the ecliptic and the designated star (or other point of the heaven).

It is clear, moreover, that latitude likewise is of two kinds, one northern [Boream], the other southern [Auſtrinam], according as the star lies to the north or to the south of the ecliptic.

So in the figure given above: since NM is the ecliptic, O the north pole of the ecliptic and P the south pole, and ONPM that same solstitial colure, both the colure itself and the dotted circles OQP, ORP, OSP, OTP,

OVP will be circles of latitude. The latitude of the star K (a northern one, that is) will be the arc VK; the latitude of the star L (a southern one) the arc TL.

It should be noted, moreover, that here too longitude [Longitudinem] is coupled with latitude. This is the name they give to the arc of the ecliptic intercepted from the beginning of ♈ up to the point at which the circle of latitude cuts the ecliptic.

So the longitude of the star K will be the arc of the ecliptic SV; of the star L, the arc ST. In the same way, when the Sun is at the beginning of ♋, its longitude will be the arc SM — that is, a quadrant, or 90 degrees; when it is at the beginning of ♎, the same arc together with the whole of the remaining hemisphere as far as N — that is, three quarters of the circle, or 270 degrees.

I pass over, further, what is evident: that a star which is on the equator lacks all declination, and one which is on the ecliptic lacks all latitude; and, besides, that neither declination nor latitude can exceed 90 degrees, or a quadrant of the circle, because each is bounded on either side at the opposite poles — whereas right ascension and longitude alike run on as far as 360, that is, along the whole course of the equator and of the ecliptic respectively, until, having set out from the beginning of ♈, one comes back to the same point.

I likewise pass over how easily one may guard against the equivocation with which geographers use the words longitude and latitude. One need only note that, when they too mark out on the Earth an equator and meridians, or circles passing through the poles, they call longitude what we here call right ascension, and latitude what we call declination.

CAPVT XV.

Chapter 15.

De triplici poſitu Sphæræ, Recto, Obliquo, Parallelo.

On the threefold position of the sphere: right, oblique and parallel.

Having so far set out the circles of the sphere, it follows that we should touch briefly — as we have already hinted once or twice in connection with the horizon — on what kinds of position there are, according to which the sphere is established as right [Recta], oblique [Obliqua] or parallel [Parallela]. And the same can be understood, in proportion, in the world itself.

A sphere, then, is called right in which, with each pole lying on the horizon, the stars rise and set straight — or, in other words, ascend and descend making right angles with the horizon. Hence in such a position the horizon too is called right.

Oblique is the sphere in which, with one of the poles raised above the horizon and the other depressed below it, the stars rise and set obliquely — or, in other words, ascend and descend making oblique angles with the horizon. Hence in such a position the horizon too is called oblique.

Parallel is the sphere in which, with one of the poles placed at the zenith and the other at the nadir, the stars neither rise nor set — or, in other words, neither ascend nor descend — but are carried with a motion parallel to the horizon. Hence in such a position the horizon too is called parallel.

The threefold position can be represented as follows.

Diagram. The right sphere. A circle with a vertical and a horizontal diameter; the half below the horizontal diameter is shaded. The horizontal diameter is the horizon, with a pole at each end of it outside the rim; the vertical diameter is the equator, its label running down the line and broken across the horizon. The zenith is marked above the top of the circle and the nadir below its foot.

- [[Z/z]]enith (above the rim, top): zenith
- Polus (outside the left rim, set vertically, at the end of the horizontal diameter): pole
- Aequ- (down the vertical diameter, above the horizon): equator (first part of the word)
- Horizon (on the horizontal diameter, left of the vertical): horizon
- Rectus (on the horizontal diameter, right of the vertical): right — read with *Horizon*, "right horizon"
- Polus (outside the right rim, set vertically, at the end of the horizontal diameter): pole
- ator (down the vertical diameter, in the shaded half): equator (end of the word)
- [[N/n]]adir (below the rim, foot): nadir

Diagram. The oblique sphere. A circle with a horizontal diameter, the half below it shaded, and two diagonals crossing at the centre: one runs from a pole outside the upper-right rim to a pole outside the lower-left rim[1]; the other

[1]identified as the axis by the translator; no label is printed on this line

runs from the upper-left rim to the lower-right rim and carries the label of the equator, broken across the horizon. The zenith is marked above the top of the circle and the nadir below its foot.

- [[Z/z]]enith (above the rim, top): zenith
- Polus (outside the upper-right rim, at the end of the first diagonal): pole
- Aequa (along the second diagonal, upper left of centre): equator (first part of the word)
- Horizon (on the horizontal diameter, left of centre): horizon
- obliqus (on the horizontal diameter, right of centre): oblique — read with *Horizon*, "oblique horizon"
- tor. (along the second diagonal, in the shaded half): equator (end of the word)
- Polus (outside the lower-left rim, at the other end of the first diagonal): pole
- [[N/n]]adir (below the rim, foot): nadir

Diagram. The parallel sphere. A circle with a vertical and a horizontal diameter; the half below the horizontal diameter is shaded. The vertical diameter runs from a pole just inside the top of the rim to a pole just inside its foot. The horizontal diameter carries the label of the equator above it and, below it in the shaded half, two fainter labels read as horizon and parallel [?]. The zenith is marked above the top of the circle and the nadir below its foot.

- [[Z/z]]enith (above the rim, top): zenith
- Po lus (just inside the rim at the top, split by the vertical): pole
- Aequa (above the horizontal diameter, left of the vertical): equator (first part of the word)
- tor. (above the horizontal diameter, right of the vertical): equator (end of the word)
- Horizon (below the horizontal diameter, left of the vertical, in the shaded half): horizon
- Paralle[?] (below the horizontal diameter, right of the vertical, in the shaded half; the end of the word runs to the rim and is not read): parallel [?]
- Po lus (just inside the rim at the foot, split by the vertical): pole
- [[N/n]]adir (below the rim, foot): nadir

In the right sphere all the stars [Aſtra] rise and set. In the oblique sphere some rise and set; some never rise, but always lie hidden below the horizon; some never set, but are perpetually above the horizon. In the parallel sphere, as has already been said, none either rises or sets; but one part is always above the horizon and the other always below — except that, with the equator coinciding with the horizon in one and the same circle, and half of the zodiac always raised and half always depressed, those that run through the zodiac for half of their course become visible, and for the other half invisible.

Those who live directly beneath the equator are in the right sphere; those directly beneath the poles, in the parallel sphere; and those who dwell in the places lying between the equator and either pole, in the oblique sphere.

In the right sphere there is a perpetual equinox: day and night alike are always of 12 hours. This is because the Sun, wherever it may be in the zodiac, stays as long above the horizon as below it, since all its circuits (or parallel circles, as it were) are constantly bisected by the horizon.

In the parallel sphere the day lasts six whole months without a break, and the night likewise six months without a break. This is because the Sun remains above the horizon for six whole months, just as it remains above the equator (that is, while for three it climbs in its circling and for three it descends), and below it in the same way.

In the oblique sphere there is inequality of days and nights. For from the equator onward toward the elevated pole, the arcs of the Sun's daily motion (namely those above the horizon) are greater than a semicircle, and the nocturnal arcs, toward the depressed pole, are less. And this indeed in such a way that, on this side of the equator (for example), the longest day, which falls when the Sun is at the beginning of ♋, gradually becomes, as one moves toward us, 13, 14, 15 hours; here at Paris it is 16, and further on it goes on becoming 17, 18 and so on, until, for those who live under the polar circle (where the tropic of ♋ itself is the greatest of the visible circles, and so grazes the horizon), it is of 24 hours. And since, proceeding further from there, the Sun's stay above the horizon comes to be of more and more days, and even becomes of one month, and of two, and of three, and of four, and of five, and finally, under the pole, of six. The same must be understood, in the same proportional manner, of the night when the Sun is beyond the equator.

Here it is worth considering that there is no place on Earth that does not have, within a whole year, six months of daytime and likewise six months of nighttime, inasmuch as in the parallel sphere, indeed, each period is continuous; in the right sphere it is distributed day by day in equal alternate turns; in the oblique sphere the length of the days and shortness of the nights through the summer is compensated by the shortness of the days and length of the nights through the winter. And as many continuous days as there are in summer beyond the polar circle, so many continuous nights are there in winter.

CAPVT XVI.

Chapter 16.

De Zonis, ac ideò de Ventorum Plagis per Parallelos Sphæræ circulos deſignatis.

On the zones, and therefore on the quarters of the winds, marked out by the parallel circles of the sphere.

Connected with these matters is that we should speak of the zones [Zonis] — enormous bands, as it were, which, marked out by the parallel circles of the sphere already described, have been recognized in the heavens from the most ancient times, as in that line of Virgil:

> *Five zones hold the heavens, of which one, with the flashing Sun ever red, etc.*

They have always, however, been held to be five: namely one in the middle, called the torrid [Torrida], contained between the two tropics; two at the extremes, called the frigid [Frigidæ], and enclosed between the polar circles and the neighbouring poles; and two, one on each side, called temperate [Temperatæ], and, between the tropics and the polar circles, interposed. Polybius, indeed, divided the torrid zone into two, with the equator in the middle; but he found no followers.

It should be noted, however, that whereas from Thales onward the temperate and frigid zones were separated by polar circles of the kind described above, following the ancients, Posidonius is recorded as the first to have separated them by polar circles such as are now found on spheres; and in this way he made the zones constant, whereas before they were either widened or narrowed according as the altitude of the pole varied.

Moreover, since the globe of the Earth itself lies beneath the heavens on every side, the same zones are therefore attributed to the Earth itself, as in that passage of Ovid:

> *And as two zones cut the heavens on the right, and as many on the left Side, and a fifth is hotter than they: So the enclosed mass, etc.*

What is more, it is the terrestrial zones to which it properly belongs to be named torrid, frigid and temperate. For there is also a terrestrial torrid zone, which was once believed uninhabitable on account of excessive heat, produced by the Sun's rays striking it perpendicularly; and the frigid zones likewise, on account of excessive cold, from rays falling all too obliquely. And yet not so long ago very great numbers of inhabitants were found both in the torrid zone and in the frigid zones (but most of all in the torrid).

How the terrestrial zones correspond to the celestial ones themselves can, it seems, be understood without difficulty from the following figure.

Diagram. A large circle, with a vertical diameter, is crossed by five horizontal lines: a short chord near the top, a longer chord above the centre, the horizontal diameter, a longer chord below the centre, and a short chord near the foot. At the centre stands a small circle, crossed by the same vertical and by five short horizontal lines of its own. From the ends of each chord of the small circle a straight line runs outward to the ends of the corresponding chord of the large circle, and the horizontal diameter runs through the small circle to the rim. All the letters stand on or within the small circle; the large circle carries none.

- B (top of the small circle, on the vertical): B
- K, I (ends of the small circle's top chord, left and right): K, I

- F, E (ends of its next chord, left and right): F, E
- D, C (ends of its horizontal diameter, left and right): D, C
- N (inside the small circle, just below the diameter, right of the vertical): N
- H, G (ends of its lower chord, left and right): H, G
- M, L (ends of its bottom chord, left and right): M, L
- A (foot of the small circle, on the vertical): A

Moreover, if you take the inner circle, which you see represents the Earth, as if it were the horizon of any region whatever; and if, besides the point B, at which it is cut by the meridian toward the north, and the point A, at which it is cut toward the south, you mark ten other points — namely five toward the east and five toward the west, for instance CD, EF, GH, IK, LM — at which it is cut by the equinoctial, the tropics and the polar circles; and if you then conceive that from these twelve points as many winds blow toward the point N, the centre [vmbilicum] of the horizon, or the place of the observer himself, then it will be possible to understand from this how the Ancients determined the quarters of the sky from which the winds came — except that the points marked by the polar circles were at first inconstant, for the reason already explained.

That is to say: the wind blowing from point B they called Aparktias [Greek: Απαρκτίαν (Aparktian)], Septentrio; from point A, Notos [Greek: Νότον (Noton)], Auster; from point C, Apēliotēs [Greek: Απηλιότην (Apēliotēn)] [recte: Απηλιώτην], Subsolanus; from point D, Zephyros [Greek: Ζέφυρον (Zephyron)], Favonius; from point E, Boreas [Greek: Βορέαν (Borean)], Kaikias [Greek: Καικίαν (Kaikian)], Aquilo; from point F, Argestēs [Greek: Αργέστην (Argestēn)], Skirōn [Greek: Σκίρωνα (Skirōna)], Olympias [Greek: Ολυμπίαν (Olympian)], Hellēspontias [Greek: Ελλησποντίαν (Hellēspontian)], Caurus or Corus; from point G, Euros [Greek: Εὖρον (Euron)], Vulturnus; from point H, Lips [Greek: Λίβα (Liba)], Africus; from point I, Messēs [Greek: Μέσσην (Messēn)] [recte: Μέσην], by some called Boreas, by some Aquilo, by some Caecias; from point K, Thraskias [Greek: Θρασκίαν (Thraskian)], by others Corus; from point L, Phoinikias [Greek: Φοινικίαν (Phoinikian)], Euronotos [Greek: Ευρόνοτον (Euronoton)], by others Vulturnus; from point M, Libonotos [Greek: Λιβόνοτον (Libonoton)], Altanus.

I pass over, however, how more recent writers, and sailors especially, who usually distinguish the winds as 32 in number (the horizon, that is, being divided into 32 equal parts), take account of no other of these points than the four cardinal ones, B, A, C, D. They name the winds that blow from these, in the Mediterranean Sea, *Tramontana*, *Ostro*, *Levante*, *Ponente*, but on the Ocean, *Nord*, *Sud*, *Est*, *Ouest*; those blowing from the points midway between them, in the Mediterranean, *Greco*, *Maestro*, *Sirocco*, *Garbino* (otherwise *Lebechio*), but on the Ocean, *Nord-est*, *Nord-ouest*, *Sud-est*, *Sud-ouest*; those blowing in turn from the intermediate points, by compound words, *Tramontana-Greco*, *Tramontana-Maestro*, etc., *Nord-nord-est*, *Nord-nord-ouest*, etc., always beginning with those that blow from the cardinal points; and finally those blowing from points

intermediate once again, by quarters of the eighths [per quadranteis octantium], in this way: *Quarta di Tramontana-Greco*, *Quarta di Tramontana-maestro*; *Quarta di Greco-tramontana*, etc.; *Nord-gen-esten*, *Nord-gen-ouesten*, *Nord-est-gen-norden*, etc. — always beginning with those that blow from the eight principal points.

CAPVT XVII.

Chapter 17.

De Climatibus, deque varietate Incolarum Terræ, propter Parallelos.

On the climates, and on the variety of the Earth's inhabitants, on account of the parallels.

Since, moreover, the division into zones was not enough for the ancients to mark the variety in the situation of regions on this side of the equator, they therefore judged that more parallels had to be employed, by which certain lesser zones, as it were, would be further subdivided. These were called climates [Climata] — "inclinations" [Inclinamenta], as you might say, or deflections from the position of the right sphere.

Now, each climate they bounded by two parallels, beginning from the equator, in such a way that at the parallel farther from the equator the longest day of the year was half an hour longer than at the shorter. Yet they took no account of a first climate at one extremity of which the longest day would be 12 and a half hours, as though that climate were wholly uninhabitable. Rather, they took as the first, so to speak, the one at one extremity of which the longest day would be thirteen hours — as though there the torrid zone, drawing nearer to the temperate, began to be inhabited.

They were not, however, accustomed to distinguish more climates than seven, because these amply took in all the regions then known. They indicated them, moreover, by the names of certain celebrated places contained in each, and so called them *Dia Meroēs* [Greek: Διὰ Μερόης (Dia Meroēs, "through Meroe")], *Dia S[y/i]ēnēs* [?] [Greek: Διὰ Σ[?]ήνης ("through S-ēnē")], etc. — that is, as it were, passing through Meroe, through Syene, through Alexandria, through Rhodes, through Rome, through Pontus, through the Borysthenes.

More recent writers, by contrast, since the Earth is now known far and wide, distinguish 24 of them, on account of the 24 half-hours, or 12 hours, by which the longest day increases all the way from the equator up to the polar circle, where the climates end, the longest day there exceeding all measure.

I pass over, however, the fact that each climate is usually divided, by inserting another parallel, into two parts, or still smaller zones, so that at the extremities of each of the two the difference in the longest day is one quarter of an hour. Further, these little zones, or half-climates, they called — by a special use of the word — parallels [Parallelos]; and so it is clear that 48 of them can now be distinguished.

On this reckoning, since in this city, for example, the longest day is 16 hours, it is clear on what grounds the city can be said to be situated at the end of the eighth climate, and at the same time at the end of the [?] sixteenth parallel[2].

Admittedly, astronomers no longer designate places by climates and parallels, but by elevations of the pole [polareis Eleuationes], or also (in the manner of geographers) by the very latitudes of the places, or their distances from the equator.

It should be added, however, that if any number of parallels distinguished you conceive in the sphere, then one conceives how the individual inhabitants of the Earth each have their own — those whom they call Perioeci [Greek: Περιοίκους (Perioikous, "dwellers around")], "circum-dwellers" [Circumcolas], as you might say; Antoeci [Greek: Αντοίκους (Antoikous, "dwellers opposite")], "opposite-dwellers" [Aduerſicolas], as it were; and Antipodes [Greek: Αντίποδας (Antipodas, "with feet opposite")], as it were "those having their footprints opposite", or Antichthones [Greek: Αντίχθονας (Antichthonas, "of the opposite earth")], as it were "inhabitants of the opposite land" — except that those living directly under the poles, since they are on no parallel, have only Antipodes, or Antichthones.

For in general, those who are under the same parallel are called Perioeci of one another; but specifically, those on opposite parts of the meridian, that is, in different halves of it from pole to pole. Antoeci are those under parallels equally distant on this side of the equator and beyond it, but taken on the same part of the meridian. Antipodes, or Antichthones, are those situated under parallels equidistant on either side of the equator, but on opposite parts of the meridian.

It is well known, moreover, that from this difference in the situation of the inhabitants there arises that variety of days and nights and of seasons by which, for the Perioeci, day and night fall at different times, but summer and winter at the same; for the Antoeci, on the other hand, day and night fall at the same times, but summer and winter at different ones; and for the Antipodes, finally, day and night, as well as summer and winter, fall at altogether different times.

It should also be added that the inhabitants of all the parallels contained within the tropics are usually called Amphiscii [Greek: Αμφισκίους (Amphiskious, "with shadow on both sides")], as it were "having a shadow on either side" (the noon shadow, that is), inasmuch as when the Sun is to the north they have their shadow turned toward the south, and when it is to the south, they have it turned toward the north. The inhabitants, on the other hand, from the tropics inclusive all the way to the polar circles are called Heteroscii [Greek: Ετεροσκίους (Heteroskious, "with shadow on one side")], as it were having one shadow only (as we have, toward the north); and that what Lucan says of the Arabs who lived within the torrid zone and had arrived in the temperate zone bears directly on this:

[2]the page prints *Paral-* at a line end and *cimi-ſexti* at the start of the next line, with no letters between

You Arabs have come into a world unknown to you, marvelling
that the shadows of the groves do not fall to the left.

Finally, the inhabitants from the polar circles up to the poles inclusive are called Periscii [Greek: Περισκίους (Periskious, "with shadow all around")], as it were, with the Sun not setting, having a shadow carried round through every quarter of the horizon. I say "with the Sun not setting", because, apart from those who live under the poles, the Sun at times both rises and sets for the rest, and at that time they can be counted among the Heteroscii.

CAPVT XVIII.

Chapter 18.

De Crepuſculis, quæ ad horizontem in quovis Sphæræ ſitu viſuntur.

On twilights, which are seen at the horizon in any position of the sphere.

Since the motion of the primum mobile, which is demonstrated by turning the sphere round, brings about [?] the rising and setting of the stars as referred to the horizon, we who are next to speak of rising and setting must first say something about twilights and about the refractions observed at the horizon.

In the first place, twilight is nothing other than that dim [crepera], or as it were doubtful, or intermediate light, which appears both before sunrise in the region of the east, where it is specifically called dawn [Aurora], and after sunset in the region of the west, where it keeps the name of twilight.

The cause of it is the atmosphere, or region of vapours, with which the Earth is, as it were, clothed all round. Indeed, it extends further than the furthest visible part of the earth; it both receives the rays of the Sun, while the Sun is below the horizon, earlier in the morning, and loses them later in the evening, and by reflecting them toward us it makes itself appear bright.

That is to say, if there were no vapours, but only the purest air, we would see no light at all either before sunrise or after sunset; instead, the passage would be from sheer darkness to daylight, and from daylight to sheer darkness.

It should be noted, however, that the beginning of the morning twilight and the end of the evening twilight occur when the Sun is about eighteen degrees below the horizon, taken along a vertical circle, or perpendicularly. And because the less the Sun is distant from the horizon, the more of the atmosphere standing above the horizon it lights up, the twilight therefore also becomes correspondingly brighter.

I pass over the fact that it has been inferred from this that the height of the atmosphere above the earth is about 40 Italian miles; although it seems to be much less, since that first and last light can be produced not directly by the Sun, but by reflection from the lower parts of the same atmosphere.

I note rather that twilight is shortest in the right sphere for this reason: whatever parallel the Sun is on, its ascent and descent are perpendicular, and

those eighteen degrees are used up very nearly as much in the parallel as in the vertical. In the oblique sphere, on the other hand, twilight is longer, because the arc of the parallel between the point of the Sun about to rise or set on one vertical circle and the point of the eighteenth degree on another vertical circle — the arc intercepted between them — lies obliquely, and is therefore longer than eighteen degrees. Hence also, because this arc is longer in summer than in winter, it comes about that summer twilight is longer than winter twilight. In this city, for example, while in winter it does not reach two hours, in summer it nevertheless comes very close to four.

Moreover, it can be observed that in this city the evening twilight runs on into the morning twilight for eight days before and as many after the summer solstice. Thus twilight does not fail even at midnight, because the Sun is not then sunk a full 18 degrees below the horizon; at the solstice itself, in fact, it falls 20′ short.

There is no need, however, to point out that twilight will run on for correspondingly more days, and will turn out correspondingly brighter even at midnight, the more oblique the sphere is. For the Sun will be correspondingly nearer the horizon, until, completing its circuit above the horizon (namely under the polar circle and beyond), it produces a day that is both continuous and without any twilight.

It should not be left out, further, that the obliquity of the horizon and the inequality of the parallels are the reason why, although twilight is at its greatest and longest at the summer solstice, it is nevertheless not at its shortest at the winter solstice; in this city, indeed, it is shortest around March 1 and around October 12.

Finally, in the parallel sphere, twilight is continuous for nearly 52 days, because the Sun is not 18 degrees away from the horizon, taken along a vertical circle, either any sooner when descending or any later when ascending.

CAPVT XIX.

Chapter 19.

De Radiorum Sidereorum Refractionibus, quæ ad horizontem maximè contingunt.

On the refractions of the rays of the heavenly bodies, which occur chiefly at the horizon.

As for refractions: it is known that rays passing obliquely from a rarer medium into a denser one are refracted and bent toward the ray that is taken as perpendicular (just as, conversely, rays passing from a denser into a rarer medium are refracted and move away from that same perpendicular). Therefore the rays of the Sun and of the other heavenly bodies, as they fall obliquely from the purest aether into the atmosphere already mentioned and are about to pass through it, are refracted toward the perpendicular, that is, toward the ray

directed from the Sun toward the centre of the earth, which is the same as the centre of the atmosphere.

And because the rays travelling toward us are most oblique to the perpendicular when the heavenly body is on the horizon, the refraction is greatest at that time. It amounts, for the stars, to 30′, but for the Sun and the Moon to 33′ or 34′; and it is found to be correspondingly smaller the higher the heavenly body is raised, so that a star above the twentieth degree of altitude, and the Sun and the Moon above the 35th or 38th, undergo no perceptible refraction.

This horizontal refraction, moreover, has the effect that the Sun, for example, standing on the horizon and seen by a refracted ray, appears to us higher by 34′ or thereabouts than it really is, and than it would appear if the vapours were removed and it were seen by a direct ray. And since its diameter is half a degree, or 30′, it can therefore be seen whole, even though it is in fact wholly below the horizon.

This happens just as when you place a pebble at the bottom of a basin and hold your head so that the rim of the basin keeps you from seeing the pebble, which you will nevertheless see once water is poured in, though pebble and eye stay unmoved. That is, the ray that, running direct, used to end at your forehead is so refracted in passing from the water into the air that it reaches the eye and makes the pebble visible to it.

Incidentally, this is the reason why sometimes, while the Moon is suffering an eclipse because the Earth is interposed between it and the Sun, both luminaries are nevertheless observed standing above the horizon. In truth each of them is below, although because of the refracted rays it appears to stand above.

From the same cause, too, it came about that in Novaya Zemlya [Noua Zembla], after a continuous night of two and a half months, the Dutch recovered the Sun some days earlier than would rightly have been expected: the atmosphere, that is, raised its image.

I pass over, however, the fact that the obliquity with which the image of the Sun glides into the atmosphere, relative to us, is the reason why the Sun near the horizon appears not precisely circular but elliptical, or oval in shape;

having, that is, its perpendicular diameter more contracted than its transverse one.

CAPVT XX.

Chapter 20.

De Ortu, Occaſuque Siderum Horizontali.

On the horizontal rising and setting of the heavenly bodies.

To say something now about the rising and setting of the heavenly bodies: this is customarily distinguished, in general, as twofold, astronomical and poetical. Not that astronomers do not also concern themselves with the latter; but the poets use it above all, neglecting the other.

Now since the astronomical rising and setting is nothing other than right or oblique ascension and descension, considered with respect to the equator, therefore, since right and oblique ascension have already been discussed, there is no reason for it to detain us here at all.

The poetical, on the other hand, is reckoned either with respect to the horizon, above which the heavenly bodies emerge or below which they sink; or with respect to the Sun, from whose rays the other heavenly bodies are either freed or hidden.

The one reckoned with respect to the horizon is further distinguished as twofold: one is called cosmical [Coſmicus], the other acronychal [Acronychus].

Cosmical — "worldly", as it were [quaſi Mundanus] — rising, and setting likewise, is the one observed properly about the very time of sunrise (as though the world, or the face of Nature, were then renewed). For if a star rises at the time the Sun rises, they say it rises cosmically. And if, again, at the time the Sun rises (for I stress this, so that confusion may be avoided) some star sets, they say it sets cosmically.

By cosmical rising, Taurus is understood to rise in the month of April, when it rises together with the Sun, which is in it; as in that line of Virgil:

When white, with gilded horns, he opens the year, the Bull —

By cosmical setting, the Pleiades [Pleïades] are understood to set in autumn itself, when, as the Sun rises together with Scorpio, in which it is, the Pleiades, which are situated in Taurus, go below the horizon on the opposite side; as in that line of the same poet:

Let the Atlantides of the dawn be hidden from you before you commit to the furrows the seed that is due. —

I say "properly", however, because they also count it as rising and setting cosmically (though less properly) when a star rises or sets during the day, that is, while the Sun is above the horizon.

Acronychal rising, on the other hand, and setting likewise, is the one observed properly about the very time of sunset, or the beginning of night; from this the name was formed (they call it "chronical", in fact, corruptly). For if a star sets together with the setting Sun, the setting is acronychal; and if, again, at sunset (for I stress this here too) a star rises on the opposite side, it is held to be an acronychal rising.

By acronychal rising, the Pleiades are understood to rise in autumn, rising together, that is, with Taurus, in which, as has been said, they are situated, while the Sun, staying in Scorpio, sets on the opposite side; as in that line of Ovid:

Since I have been without you, thrust out to the Scythian shores, the rising Pleiad has made four autumns.

Here you see, incidentally, that the same autumn is expressed by Virgil through the setting, but by Ovid through the rising, of the same Pleiades. But, of course, this is according as the former means the cosmical setting, for at that

time the Pleiades set in the morning; the latter means the acronychal rising, for the same stars then rise in the evening.

Examples of acronychal setting are rarer. For as to their claim that Sagittarius [Sagitarium] is to be understood as setting by this setting, when Lucan, meaning to describe the twilight near the summer solstice, says:

> — *For the Sun held the Ledaean stars, when the light is at its highest, with Cancer near; the short night was then pressing on the Thessalian Arrows;*

it is clear that Sagittarius could not set then except cosmically — when, say, the Sun rises with Gemini; and that it can obtain an acronychal setting only when the Sun is in it and sets together with it.

Here too, however, I say "properly"; for less properly they also call acronychal the rising and setting that takes place during the night, that is, while the Sun is below the horizon.

Note, accordingly, that both the cosmical rising and the cosmical setting can be called "morning" [Matutinum], and both the acronychal rising and the acronychal setting can be called "evening" [Veſpertinum].

CAPVT XXI.

Chapter 21.

De Ortu, Occaſuque Siderum Heliaco.

On the heliacal rising and setting of the heavenly bodies.

The rising and setting of the other heavenly bodies that is reckoned with respect to the Sun is usually called heliacal [Heliacus], from the Sun itself, which in Greek is Ηλιος [Greek: Ηλιος ([H?]ēlios, "Sun")].

Further, a star is said to set heliacally [Heliacè] when, having previously been seen in the morning or in the evening because of its distance from the Sun lying below the horizon, it can no longer be seen from then on, because of the nearness of the Sun and the star's immersion in the solar rays — since by their brilliance whatever lies round about is overcast and, so to speak, vanishes.

A star is said to rise heliacally, on the other hand, when, having previously been invisible because of the nearness of the Sun and its rays, it begins from then on to be visible in the morning or in the evening, because of the distance it has gained from the Sun and its emergence from the Sun's brilliance.

The reason why some heavenly bodies set in the morning and rise in the evening is that, in their own motion through the zodiac — that is, eastward [in ortum] — they are faster than the Sun; and so they catch it up in the morning and leave it behind in the evening.

Of this kind is the Moon, which, it is agreed, by its eastward motion both goes under the Sun's rays in the morning and comes out of them in the evening.

The reason why some set in the evening and rise in the morning is that the Sun, in its motion through the zodiac, is faster than they are; and so it

catches them up with its brilliance in the evening and leaves them behind in the morning.

Of this kind are both the fixed stars and the three superior planets, Saturn, Jupiter and Mars. The poets, moreover, celebrate above all the setting and rising of the fixed stars. Thus Ovid alludes to the setting of the Dolphin, while the Sun is running through Capricorn, in this distich:

> *The Dolphin you saw just now studded with stars will flee your sight on the following night.*

In the same way Virgil alludes to the setting of the Dog (understand: the Greater Dog, which, as we have already said, is also called Canicula and Sirius), when the Sun is near the end of Taurus, in these lines:

> *When the white Bull with gilded horns opens the year, and the Dog, giving way to the star that faces it, sets.*

So too the heliacal setting of the Northern Crown, at the time of the cosmical setting of the Pleiades, which we have already mentioned, in these lines:

> *Let the Atlantides of the dawn be hidden from you first, and the Gnosian star of the blazing Crown withdraw, before what is owed to the furrows, etc.*

Thus Ovid alludes to the rising of Aquarius, when the Sun is about to enter Pisces, in this distich:

> *Now light Aquarius has sunk down with his tilted urn; you who come next, Fish, receive the horses of the sky.*

And there is hardly any author who has not celebrated the rising of the Dog Star [Caniculæ], as also the 30, 40 or 50 days following it (the authors differ, of course), which are called from it the dog days [Caniculareis].

I pass over, however, the question whether such days, which were formerly counted from about July 17, the day on which the rising of the Dog took place, ought still to be counted from that same day, as is commonly done; since the rising of the Dog now occurs only around the middle of August.

I said "superior" planets, however; for the two inferior ones, Venus and Mercury, sometimes rise in the morning and set in the evening, and sometimes rise in the evening and set in the morning.

The reason is that they circle the Sun and do not always direct their course eastward, but sometimes also go back westward, as will be explained in its place. It follows that, since on other grounds they are faster than the Sun itself, at one time they catch it up in the morning, while they are approaching from the west, and leave it behind in the evening, while they go on advancing towards the east; at another time they run into the Sun in the evening, while they are going back from the east, and leave it behind in the morning, while they go on moving towards the west.

CAPVT XXII.

Chapter 22.

De partibus Temporis (cuius menſura eſt Primus Motus reuolutione Sphæræ deſignatus) ac primùm de Die.

On the parts of time (whose measure is the first motion, marked out by the revolution of the sphere), and first on the day.

It has been said before that the revolution, or motion, of the primum mobile [Primi Mobilis] — which is usually explained by means of the sphere, and is observed above all with respect to the equator — is the measure of time. It is therefore not out of place to add here a few things about the parts of time, insofar as they fall under a measure of this kind.

Since the day presents itself first, as the time than which none is better known, it should be noted that "day" is taken in two ways, as has already been suggested before: first, namely, for the duration of one entire circuit of the Sun around the Earth and secondly for the duration, or stay, of the Sun above the horizon. In the former sense it is customary to call it the natural day [Diem Naturalem], in the latter the artificial day [Artificialem].

The natural day — which is also called Νυχθήμερος [Greek: Νυχθήμερος (Nychthēmeros, "night-and-day")], as if to say *Noctidialis*, "night-day", because it comprises both the artificial day and the night as well — is either astronomical or civil.

The astronomical day is the space of time in which one entire revolution of the equator is completed, together with the portion of that same equator which corresponds to the portion of the ecliptic that the Sun traverses in the meantime.

For if the Sun did not move along the ecliptic, and returned to the meridian with the same point of the equator with which it leaves the meridian (for example), then one entire revolution of the equator would measure the day exactly. But because the Sun is continually carried forward, and daily by about one degree eastward, it follows that when the point of the equator with which the Sun departed comes back to the meridian, the Sun has not yet come back, but does so about one degree later.

"About", I say; for partly because of the obliquity of the zodiac, and partly because of the eccentricity [Eccentricitatem], of which we shall have to speak below, sometimes somewhat more and sometimes somewhat less than one degree has to be added; and from this, accordingly, a certain inequality of days arises.

Note in passing, however, that whereas the Sun in its mean motion traverses 59 1/6′ of the zodiac, or ecliptic, each day, it sometimes traverses about two minutes more, and sometimes about two less.

The civil day is the one which, according to a city's or nation's common law or custom, is fixed with respect to its beginning or its end. Thus the Babylonians of old began the day from the rising of the Sun (as the people of Nuremberg still do today); the Jews and the Athenians from its setting (as the Italians, Austrians, Bohemians and Silesians still do); the Egyptians from

midnight (as the Mysienses still do — indeed, so do we too, except that we seem, like the Germans, to make a double beginning, inasmuch as, once 12 hours are completed at noon, we begin the remaining 12 again from one); the Umbrians from noon (as the Arabs and most others still do). Not to mention that the astronomers, too, begin the day from noon — except that the so-called Prutenic Tables set its beginning at midnight.

What variety there is, moreover, among feast days, working days, assembly days and the rest of this kind, it would be an endless task to tell, since each nation has its own in particular.

Concerning the artificial day, taken as the Sun's stay above the horizon, what has been said about the manifold position of the sphere should suffice.

It need only be added here that the artificial days increase and decrease unequally because of the obliquity of the zodiac. For around the equinoxes they increase and decrease quite perceptibly, because the diurnal arcs are considerably enlarged and contracted; around the solstices, however, very imperceptibly, because the diurnal arcs are increased or diminished by almost nothing.

CAPVT XXIII.

Chapter 23.

De Hora.

On the hour.

It is usual for the day to be resolved, by its nearest division, into hours, and to grow, by its nearest composition, into weeks.

The word *hora* is indeed an ancient one, but it was taken, namely, for a season [tempeſtate]; for it came to be used later for the twenty-fourth part of the day, since among the ancients the day was hardly divided in any other way than into morning, midday and evening time.

There are, moreover, two kinds of hours: some are called equal, others unequal.

The equal hour (which is also usually called equinoctial) is the twenty-fourth part of the natural day; or the time in which 15 degrees of the equator pass the meridian (except that a slight addition arises, for the reason mentioned not long before). And this is the kind of hours which the astronomers have always used, and which almost all nations now use.

I pass over, however, the fact that the astronomers divide such an hour into 60 *scrupula*, or first minutes; each first minute again into 60 seconds; each second into 60 thirds, and so on, as was indicated above; whereas the calendar computists divide the hour into 4 quarters, or "points" [puncta] as they call them, and subdivide each point variously into *ostenta*, moments, and so on.

The unequal hour (which is also called temporary [Temporaria]) is the twelfth part of the artificial day, and likewise the twelfth part of the night: each artificial day, that is, is divided into twelve equal parts, and the night in the

same way. It is therefore called unequal not by comparison with the other hours of the same day, but with the hours of other days; for it is established that the daytime hours in winter are much shorter than the daytime hours in summer, and that the night hours in winter and in summer are the opposite.

The Jews used this kind of hours, as is understood from various passages of Scripture. In them the first hour is the one that immediately follows the rising of the Sun; the third is the one we call nine in the morning (understand this, however, chiefly around the equinox itself); the sixth, what we call noon; the ninth, what we call three in the afternoon; and the eleventh, the one after which only one remains before the setting of the Sun.

That the Greeks used the same kind can be understood if only from the fact that Achilles Tatius asks, and explains, why in that region the Sun was said to make a day of 15 hours at the summer solstice and of nine at the winter solstice, whereas in mechanical clocks and water clocks the day appeared always to consist of 12 hours.

That the Romans, too, used the same kind is proved by countless passages of the authors, such as, for example, these:

> *The first hour and the second hold the morning callers; the third keeps the hoarse advocates at work, etc.*

And:

> *We snore — enough to sleep off untamed Falernian — while the line is touched by the fifth shadow.*

This is where it is established that the eleventh hour of the morning is meant, that is, one hour before noon.

CAPVT XXIV.

Chapter 24.

De Hebdomade.

On the week.

That the week is the most ancient of all groupings of days is plain from the sacred text of Genesis.

It is established that almost all the Eastern peoples have used it from time immemorial, but the Western peoples only since the Christian faith was received. For the Greeks used, rather, a decade [Decade], and the Romans an ennead [Enneade].

The pagans named each day of the week after a separate planet; and these names are still commonly kept among us, except that in place of the day of the Sun we say the day of the Lord, or the Lord's day [Dominicam], out of reverence for the day on which Christ the Lord rose from the dead; and in place of the day of Saturn, the day of the Sabbath, as if to say the day of rest, in memory of the day on which God, as we read, rested in the beginning from all the work that he had accomplished.

But why does the day of the Moon follow the day of the Sun, and after it the day of Mars, and so on, when the order in which the planets stand in the heavens is nowhere kept?

This is to be understood from a circle whose circumference is divided into seven equal parts, and from

each end of every part lines are drawn to the opposite point, so that seven isosceles [æquierura] [recte: æquicrura] triangles are formed, at whose apexes the planets are placed in order, as can be seen in the accompanying figure.

Diagram. A circle with a seven-pointed star inscribed in it, each point of the star touching the circumference. The seven planetary signs stand outside the circle, one at each point; the figure carries no letters.

- ♄ (above the top point): Saturn
- ☾ (outside, upper right): the Moon
- ☿ (outside, right): Mercury
- ♀ (below the lower-right point): Venus
- ☉ (below the lower-left point): the Sun
- ♂ (outside, left): Mars
- ♃ (outside, upper left): Jupiter

That is, if from ♄ you follow the course of the line that runs to the left, you will come to the Sun; if from the Sun you follow the course of the other line, you will come to the Moon; if from the Moon the other line, to Mars; and so on, in the order in which the days of the week are named.

From this you will also understand how it comes about that people think this order follows from the dominion they assign to the planets, one to each hour. For since they hold [velin] [recte: velint] that in the first hour of the day (beginning from noon) the planet that gives the day its name rules, and in the second hour the planet that follows it in the order they hold in the heavens, going downward; and in the third hour another, and so on, also returning to the highest once the lowest has been reached, according to these popular verses:

> *Moon, and Mercury, Venus, and Sun, Mars, Jove, Saturn, In retrograde*
> *order each claims an hour for itself:*

when they hold this, I say, it will come about that, if you assign the planets one to each hour, then once you have reached the twenty-fourth, the planet that follows for the twenty-fifth hour, that is, the first of the next day, is the one that gives that day its name. This will become plain by going round the circle drawn above.

In Church usage, however, we name the days by the name and order of the ferias [Feriarum] (except that in place of the first feria we again say the Lord's day [Dominicam], and in place of the seventh the Sabbath). This is because the old ecclesiastical year began at Easter, and all the days of its first week were holidays (although now there are no more than three); and from this it came about that the days of the following weeks too, following the precedent and in imitation of that first week, are called ferias.

CAPVT XXV.

Chapter 25.

De Menſe.

On the month.

The month is properly the time of the Moon's course through the zodiac; but under this name also comes the time in which the Sun runs through a twelfth part of the zodiac; so one month is called lunar and another solar.

The lunar month, moreover, is either periodic or synodic; and some also distinguish a further month, which they call the month of illumination [Illuminationis].

The periodic month is the space of time in which the Moon, having set out from one point of the zodiac, returns to that same point; it is 27 days with about a third of a day.

The synodic month is the time in which the Moon, having set out from conjunction with the Sun, returns to the next conjunction; it is 29 days with about half a day.

For after the Moon has returned to the point at which it was in conjunction with the Sun, it must still advance two days and more to overtake the Sun, which has not meanwhile ceased its motion.

The month of illumination is their name for the time that runs from when the Moon first appears, new, in the evening, until, now old, it is hidden in the morning; it is roughly 26 days.

The solar month, if a mean is taken between a slight excess and a slight defect, is 30 days and 10 hours, with about half an hour more.

Further, since one month is distinguished as astronomical and another as civil: the astronomical month is properly the lunar one, both periodic and synodic, but the synodic above all.

Civil months, on the other hand, are those that the various states and nations each use according to their own institutions; for some prefer lunar months, others solar.

Lunar months were used in the past by the Jews, the Greeks, the Romans and others (and the Muslims [Mohammedani] use them now as well), but they were synodic months. Since, however, those halves and other fragments of days of that kind have no place in civil use, it became customary for months to be reckoned alternately of 30 and of 29 days, and to be called full and hollow [Pleni, & Caui].

The Egyptians used solar months, but ones that were nevertheless all of 30 days. For the five days made up out of those fragments of ten hours they put off to the end of the year; and the nearly six hours made up out of those halves they treated as of virtually no account.

We too can be said to use solar months, even though we distribute the twelve parts of the solar circuit among them unequally, and collect those six

hours only every fourth year and count them as one day, which is inserted between the 23rd and the 24th of February.

I pass over the fact that it was Julius Caesar who, in changing the lunar year received from Romulus onward, and from Numa, into a solar one, partly retained and partly created this inequality of the months, as Macrobius and others relate.

I also pass over the various names given to the months by various peoples. For it is common knowledge that our March and the months following it were instituted and named by Romulus (except that after Caesar's death July [Iulius] was so called in place of Quintilis, and August in place of Sextilis), while January and February were added, and so named, by Numa; and it is well known that the months of the Greeks are called Hecatombaeon, Anthesterion, Elaphebolion and so on, and those of the Jews Tishrei [Tiſri], Marcheshvan [Marcheſuan], Kislev [Caſleu], and so on and those of the Egyptians Thoth, Paophi, Athyr, and so on — to say nothing of the rest.

Finally, I pass over the various names for the days and for the parts of the month: of this kind were, among the Romans, the Kalends, Nones and Ides [Kalendæ, Nonæ, Eidus], and among the Greeks the Neomenia, the Decas, the Eicas, and so on.

CAPVT XXVI.

On the Year.

Although "year" is sometimes taken for the time of the revolution of any planet through the zodiac (and indeed sometimes even for a complete revolution of the firmament along that same zodiac, since some call this the Great Year [Magnum Annum]), nevertheless a year, properly speaking, is the time in which the Sun traverses the whole zodiac.

Now the year is usually divided into the astronomical and the civil; and of the astronomical, one kind is usually called the vertent year [Vertens], the other the sidereal [Sidereus].

The vertent year is the one in which the Sun, having set out from some one point of the zodiac (as of an equinox or of a solstice), returns to that very point; the sidereal, the one in which, having set out from some star, it comes back to that very star.

And since the sidereal year is imperceptibly longer than the vertent, because of the motion of the fixed stars toward the east, which we touched on just now and of which more will be said below, the vertent year contains 365 days with 5 hours and approximately 49 minutes.

The civil year is the one which states or nations at their own discretion use; and they do so either by considering only the motion of the Sun, or by bringing in the motion of the Moon as well. Hence one year is called solar and another lunar.

CAPVT XXVI.

The solar year either always consists of 365 days — the kind we have already indicated was in use among the Egyptians, made up, that is, of twelve months of thirty days each and five days which were called [Greek: ἐπαγόμεναι (epagomenai, "added days")], that is, "added on" [ſuperadjecti].

At this point it should be noted that, since the Egyptians took no account of those nearly six hours left over each year, it regularly happened that within 1640 years the equinoxes and solstices ran through all the months of the year and all the days of the months. Thus if, for example, the equinox falls this year at noon on March 20, a year later it will fall at 6 in the evening of the same day; a year after that, at the following midnight; a year after that again, at 6 in the morning of the 21st; and finally after the fourth year, at noon on that same 21st; and proceeding in the same way, after another four years at noon on the 22nd, and so on.

Or else every fourth year in order consists of 366 days: a day, that is, is intercalated, which, as we have already indicated, is made up from those nearly six hours held in reserve. Moreover, it is well known that the intercalation is made so that the equinoxes and solstices are kept within the same months and the same days of the months, and do not run on, as we said happened among the Egyptians.

It is also well known that this fourth year is called bissextile [Bis-ſextilem] because, when the intercalation is made by inserting that day between February 23 and 24, there is said in that year: "twice on the sixth day before the Kalends of March" [bis, Sexto Kalendas Martij].

I say "nearly six hours", however, because approximately 11 minutes are lacking. From this, then, it is understood that what is added in each bissextile year is too much, and that for this reason the equinoxes and solstices can gradually run off — not forward, but backward. And so it came about that, whereas at the time of the Council of Nicaea the vernal equinox fell around March 21, within the memory of our fathers it was found to fall around the 11th of the same month; so much so that in the year of Christ 1582, 10 days were suppressed, so that it would return to the 21st.

I pass over, however, the point that, because this reform, called the reform of the calendar, was made by Gregory XIII, Supreme Pontiff, the form of the year that we now use is therefore called Gregorian, and new; whereas the old form, which the provinces that have not embraced the reform still keep (accordingly reckoning the equinoxes, solstices and other seasons of the year a full ten days later than we do), is called Julian, as being the very same — that is, without any interruption — as the one instituted by Julius Caesar.

The lunar year is the one that consists of 12 synodic lunar months, or of 354 days with approximately a third, that is, eight hours; and so it is shorter than the solar year by about 11 days. Because we add these each year in order to fit the lunar course to the solar, we therefore call them epactal days, or epacts [Epactaleis, Epactaſ-ve].

CAPVT XXVI.

The ancients, since they held the lunar year to be of precisely 354 days, and therefore reckoned that 11 days and a quarter were lacking to make up the solar year — days which within eight years would come to 90 days — accordingly took these days and made months out of them (called [Greek: ἐμβολίμους (embolimous, "intercalary")]): either three, of thirty days each, which they intercalated after the third, fifth and eighth years, as the Greeks did; or four, alternately of 22 and 23 days, which they intercalated in alternate years, the second, fourth, sixth and eighth, as the Romans did.

The Romans, moreover, intercalated them after February 23, that is, after the Terminalia (so that it is less surprising that the same time was chosen for intercalating the bissextile day), whereas the Greeks intercalated rather between the 5th and 6th months. Hence, because their sixth month was Poseideon [Poſideon], the intercalated month was called First Poseideon [Poſideon prior]. In the same way, among the Jews too, the month intercalated before the 6th, which is Adar, was called First Adar [prior Adar].

Nothing need be added here about the beginning of the year, which, as is well known, has always differed among different nations. For while the Egyptians had a beginning that wandered through the whole cycle of the year, the Jews began their ecclesiastical year from the month Nisan, that is, from the new moon nearest the vernal equinox, and their civil year from the month Tishrei, that is, from the new moon nearest the autumnal equinox. Thus the Greeks began from the new moon nearest the summer solstice; the Romans from midwinter [Bruma], that is, from the winter solstice itself — except that, because Caesar, when he instituted the year, waited for the next following new moon so as to fix on that day the Kalends of January, or the beginning of the year, this beginning of the year (which we still use) turned out to fall some days after midwinter. And so others at other times.

Nor need anything be added about the division of the year into four seasons, or three, which the Egyptians are recorded to have once counted (indeed, sometimes even months) as so many years — so that it is less surprising that they claimed so long a human life, or a life of so many years.

Nor, again, anything about the periods measured by repeated years: the Olympiad, of 4 years; the lustrum, now of 4 years, now of 5; the Indiction, of 15; the Period of Meton, or Lunar Cycle, or Golden Number, of 19; the Solar Cycle, or cycle of the Dominical letters, of 28; the Jubilee, of 49 or 50; the Period of Callippus, of 76; the century [Sæculo], of 100; the Period of Hipparchus, of 304; the Period of Dionysius, of 532; the Julian Period, recently devised by Scaliger [Joseph Justus Scaliger], of 7980; and the Great Year. The Great Year has been used not only for the revolution of the firmament already mentioned, but also for the restoration of all things to the same state they had at the beginning; and it has been held by the astrologers to be of 25, 36 or 49 thousand years, while by others it has been held to be of fewer years, and equally by others of by far the most.

CAPVT XXVII.

Chapter 27.

De Epochis Temporum.

On the Epochs of Times.

When astronomers compute the heavenly motions, they must not only posit certain points of the sky from which the motions of the stars are to be reckoned, but also, as it were, tie those points to certain moments of time, from which, as from beginnings and heads, the computation is to begin. Such beginnings, moreover, or heads [capita], are what they call Epochs [Epochas], as though they were, so to speak, certain fixed, determined and bounded moments, not wandering ones. They are also commonly called Eras [Æræ] — perhaps not so much from an old usage of the Spaniards as from a misuse, by which a singular, feminine word was made out of the neuter plural Æra; for that was the name formerly given to those little bronze studs [ærei illi clauiculi] with which reckoning-boards [Abaci ſupputatorij] were fitted. They are also called Roots [Radices], because, as plants grow from their roots, so the series of times grows from the epochs.

The most illustrious epoch of all, moreover, and the most familiar to us, is that of the Nativity of Christ, or rather the Kalends of the January that we suppose immediately followed the Nativity of Christ the Lord. From those Kalends up to the Kalends of January of this current year we say that 1645 complete years have elapsed.

For some contend that Christ was born not right at midwinter [Bruma] but around the autumnal equinox; and there are learned chronologers who maintain that he was born not only one, but even two — indeed three, four, five — years before this epoch begins. Even so, this epoch does not cease to be both approved and retained: partly because of usage, and partly because the circumstance of the act or event that gives the epoch its name or occasion makes no difference to the truth of the computation. It is enough that it be established which year, counting from it, and which moment of that year is meant, when we suppose that at that very moment the star occupied the point from which we deduce its motion, whether backwards or forwards.

It is clear, meanwhile, why they call this era the vulga- r and the Dionysian era. They call it Vulgar, that is, to distinguish it from the one they consider the true era — the one according to which we would have to count this year not as the forty-sixth beyond the one thousand six hundredth, but as either the 47th, or the 48th, or the 49th, or the 50th, or the 51st. And they call it Dionysian after Dionysius the Abbot, surnamed Exiguus [the Little], who is believed to have been its author a little more than five hundred years after Christ. From his time onwards, years began to be numbered from the Nativity of Christ itself, whereas before they were reckoned only by consuls, by Olympiads, from the founding of the City.

But to touch on some of the other epochs that have been used partly in chronology and partly in astronomy: first among the sacred epochs is rightly celebrated the epoch of the creation of the world [Orbis conditi]. However notable the controversy over it, those nevertheless seem to come closer to the truth who reckon the creation of the world at 3950 years before Christ (that is, before the vulgar epoch of Christ).

First among the profane epochs, on the other hand, is rightly held the epoch of the Olympiads, whose beginning — on account of the Olympic Games restored by Iphitus — belongs to the summer of the year 777 before Christ.

Next to it is the epoch of the founding of the City, which the more common opinion holds to refer to the year 752 before Christ.

Among astronomers the foremost epoch has always been that of Nabonassar, king (as they think) of the Babylonians. It refers to the year 747 before Christ, and indeed to the 26th day of February (a February supposed for that time), from which — coinciding with the first day of the month Thoth — the computation is made by Egyptian years, which Ptolemy and most other astronomers, Copernicus included, have used.

Next follows the epoch of the death of Alexander the Great, for which Egyptian years are likewise used. It refers to the year 324 before Christ, and to the 12th day of November.

Also celebrated, before Christ, is the epoch of Julius Caesar, which precedes the epoch of Christ by precisely 45 years.

After Christ, on the other hand, the Era of Diocletian, or of the Martyrs, was celebrated (the martyrs, that is, who suffered under him in the region of the Copts [Coptitarum], near the Nile). It is also called the Era of the Abyssinians and Ethiopians, and refers to the year of Christ 283.

Likewise the epoch of the Arabs, otherwise called that of the Hegira, or Flight of Mohammed [Muhammad], which refers to the year of Christ 622 and to the 15th day of July.

And again the epoch of the Persians, or of Iesdagird [Yazdegerd], last king of the Persians, whom Othman [ʿUthmān] defeated and killed; it refers to the year of Christ 631 and to the 16th day of June.

To these may be added the epoch of the reform of the calendar, which we discussed earlier. It refers to the year of Christ 1582 and to the 5th day of October; from that day, which was taken as the fifteenth, 10 days are thereafter lacking from the form of the Julian years.

I pass over the fact that it is now customary for both the epoch of Christ itself and the other epochs (and indeed all other times as well) to be referred to the series of years of the Period that is called Julian for this reason: because the years of which it is composed are Julian.

To grasp the manner of it: Dionysius Exiguus, already mentioned, multiplied the solar cycle of 28 into the lunar cycle of 19 and obtained a period of 532 years, at the end of which those cycles, having begun together, would begin together again. Scaliger multiplied this period into the cycle of Indictions, that is, of 15,

and obtained a period of 7980 years (the very one called Julian), at the end of which these three cycles, having begun together, can begin together again.

And since, as cycles of this kind are now in use (as, namely, for example, this year we count 3 of the solar cycle, 13 of the lunar and 14 of the Indictional), it is not possible that they began, or could have begun, except 6360 years ago (supposing, that is, that we imagine the form of our year carried back before Christ), it follows that this Period must be understood to have begun before the creation of the World.

Therefore, by extending the Period as well, we shall find that the epoch of the World falls in year 764 of the Julian Period, the epoch of Nabonassar in 3967, the epoch of Christ in 4714, and so for the rest.

INSTITVTIONIS ASTRONOMICÆ LIBER SECVNDVS, SIVE DOCTRINA THEORICA.

Book Two of the Astronomical Instruction, or the Theoretical Doctrine.

CAPVT I.

Chapter 1.

De Phænomenis varijs, quæ Secundorum Mobilium Theoriæ occaſionem fecerunt.

On the various phenomena that gave occasion to the theory of the second movables.

Just as the part of astronomy we have dealt with so far is called the doctrine of the sphere [Sphærica doctrina], from the sphere, by means of which the first motion [Motus Primus] is explained, so the part we are now taking up is called the Theoretical [Theorica], because the second motions [Secundi Motus] are explained by means of certain little machines [Machinulas], or circular figures, which people usually call theories [Theorias] (perhaps because they require a more painstaking contemplation).

Moreover, since at the outset we must first become acquainted with certain principal phenomena, from whose observation men began both to think of other motions besides the first, and to devise hypotheses [Hypotheſeis] according to which those motions might be understood to take place, the following points can therefore be noted.

First, concerning all the planets in general. They observed, first of all, that the planets rise and set now at these places of the horizon, now at those; and that under the meridian they are raised now higher towards the north, now lower towards the south — and each of these, indeed, within fixed limits. II. That they all advance now faster, now more slowly. III. That they appear sometimes larger, sometimes smaller (even apart from the question of refractions). IV. That they are configured in various ways, both with one another and also with the fixed stars; and that when they are in conjunction, sometimes the fixed stars

are covered by them, sometimes the planets are covered by one another, or some by others — and yet not all of them alike with respect to all the inhabitants of the Earth.

Next, specifically, concerning the Sun itself. I. That when it has set, it has behind it conspicuous stars that are to set after it, which a few days later no longer appear; and that when it is about to rise, it has before it inconspicuous stars, which a few days later appear and rise before it. II. That the Sun, travelling from the vernal equinox to the autumnal, takes 187 days, and from the autumnal to the vernal only 178, so that it spends nine whole days more in the northern signs than in the southern. III. That the Sun suffers eclipse, sometimes total, mostly partial — and indeed only at new moon, yet not at every new moon. IV. That the Sun's greatest declination, both to the north and to the south, has been seen to decrease; for it is not held now to be as great as it once was.

Concerning the Moon. I. That from the time it appears new, it moves away from the Sun day by day, in such a way that it keeps approaching more and more towards the more easterly stars, until it completes its circuit. II. That meanwhile it appears in various phases [Phaſibus]: namely, while waxing, horned, half-cut and gibbous on both sides; and after the full orb, while waning, it becomes gibbous again, bisected and horned. III. That it sometimes suffers eclipse, now total, now partial — and indeed only at full moon; not at every full moon, but at one falling roughly after six months. IV. That it digresses at times both to the south and to the north, now somewhat more, now somewhat less than the Sun.

Concerning Mercury and Venus. I. That such planets are, as it were, attendants [aſſeclas] of the Sun; for they do not depart far from it — Venus, indeed, scarcely any more than a sign and a half, and Mercury not even a whole sign. II. That they sometimes precede and sometimes follow the Sun. III. That they are sometimes direct, that is, they move in the order of the signs [in conſequentia], or according to the series or succession of the signs, as from ♈ to ♉ and from ♉ to ♊; sometimes retrograde, that is, they move towards the preceding signs [in Præcedentia], or against the order of the signs, as from ♈ to ♓ and from ♓ to ♒; and sometimes stationary, that is, for some time they appear to move neither against the order of the signs [in antecedentia] nor in the order of the signs. IV. That they too digress to the south and to the north, now more, now less than the Sun.

Concerning Mars, Jupiter and Saturn. I. That they are not tied to the Sun in the way the other two are, but digress from it in such a way that sometimes they are also in opposition, or stand a full six signs away from it. II. That they do indeed become, year by year, further advanced towards the more easterly stars; but that they also become at times direct, at times retrograde, at times stationary. III. That they are consistently retrograde, and at the same time fastest and largest in appearance, when they stand opposite the Sun; and that a greater extent of retrogradation belongs to Mars than to Jupiter, and to Jupiter than to Saturn; whereas, conversely, a longer time of retrogradation belongs to

Saturn than to Jupiter, and to Jupiter than to Mars. IV. And finally, that they too digress to the south and to the north, now more, now less than the Sun.

Concerning the fixed stars, finally. That they do not always keep the same distance from the equinoctial points, but also move, very slowly, in the order of the signs; and (as indeed it has seemed to some) unequally, that is, now faster, now more slowly. For Spica ♍, for example, which Timocharis observed not long after the death of Alexander to precede the point of the autumnal equinox by eight degrees, was observed two hundred years later by Hipparchus to precede it by only six; and 260 years later by Ptolemy, by not much more than three degrees; to say nothing of the fact that at the present time, that is, 1500 years later, it is observed to follow that same point by nearly 19 degrees. In the same way the first star of Aries, which in Timocharis's time was only two degrees distant from the vernal equinox, is now found to be more than 28 degrees distant; and it was said in passing earlier that the star at the very end of the tail of Cynosura, called the Pole Star [Polarem], is now only two degrees from the Pole, with a little more than half — although in Hipparchus's time it stood more than 12 away. And so with the rest.

CAPVT II.

Chapter 2.

Varia genera Hypotheſeon ſaluandis, ſiue explicandis huiuſmodi Phænomenis.

The various kinds of hypotheses for saving, or explaining, phenomena of this sort.

These, then, and others of that kind, are the things for which different people devised different schemes, so as to explain how they could come about, or appear.

In general, all of them (and Pythagoras and Plato above all) supposed that, although the celestial motions appear to us non-uniform and irregular, they must nevertheless be uniform and regular in themselves (for no irregularity [difformitatem] could belong to celestial bodies, which are immortal and divine). And so they also sought how the appearances could be saved by circular and uniform motions.

And since the general practice was to attempt this either on the supposition that the Earth is at rest or on the supposition that it moves — so that, in general, a twofold hypothesis can be distinguished — we must therefore learn here, in a few words, how manifold the former has become, since the latter (that is, the one according to which the Earth moves) is to be dealt with in the following book.

On the supposition, then, that the Earth is at rest, the first hypothesis was that of Anaxagoras, Democritus and certain others, who held that the stars move in entirely free spaces, and that there are consequently no solid spheres to which they are attached; no primum mobile by which they are swept along; no

second motion by which they are actually carried towards the east; but that only a simple motion towards the west belongs to them, and that those bodies appear to move towards the east which are carried more slowly towards the west. And so, since the fixed stars are carried westward fastest of all and complete their circuit within 24 hours, the Moon, for example, is carried slowest of all, completing its circuit, namely, only within very nearly 25 hours. And thus it is not moved by a proper motion towards the more easterly stars, but rather is left behind by the more westerly stars. Nor, they said, is the case without an example among those who race towards the same goal at an unequal pace.

Some of the more recent writers have agreed with these, and have also added that the motions of the heavenly bodies, and of the wandering ones especially, take place not directly — that is, along parallel circles towards the west — but obliquely, that is, along spirals [Spiras]; and that this is why they advance gradually from south to north and from north to south.

They ought, however, also to have added that the planets, when they appear retrograde, for example, must quicken their course, or move faster than the fixed stars; and that they then appear larger because they lower their course, that is, are carried nearer the Earth; and other similar things of that kind.

The second hypothesis was that of those who held that the stars are fastened, or as it were implanted, in solid spheres, with whose motion they would be carried round, and together with which they would be swept along (if indeed they were in the lower ones) by the highest, or first, movable [Mobili ſupremo, ſeu primo].

And it was these, properly speaking, who introduced the second motions [Secundos motus], supposing, namely, that two motions per se cannot belong to one and the same movable; but that, when one motion is per se, another can belong to it only accidentally, that is, from outside. So it is when a sailor moves per se from prow to stern, and that, say, towards the south: for meanwhile, accidentally — that is, with the motion of the ship — he is moved in the contrary direction, namely towards the north.

Further, although they subdivided the total spheres of the individual planets into several partial spheres, or orbs, some nevertheless made all these orbs homocentric [Greek: [?]μοκέντρους ([?]mokentrous, "having a common centre")] [?], that is, concentric — having the same centre as the Earth itself, or the world; others, by contrast, made them, either wholly or in part, eccentric [Greek: ἐκκέντρους (ekkentrous, "off-centre")] — that is, having their centre outside, or elsewhere than in, the Earth or the world.

The hypothesis of concentrics was introduced by Eudoxus, and enlarged by Callippus [Calippo] and Aristotle.

For Eudoxus first, besides the single sphere of the non-wandering stars [Sphæram Inerrantium], assigned three partial spheres to the Sun, as many to the Moon, and four to each of the other planets. And he did so on this principle: that in every planet the highest sphere should follow the motion of the sphere of the non-wandering stars, or primum mobile (for he recognised no other

apart from it); the next should be carried eastward in longitude; the third should produce the variation in latitude; and the fourth, in those that had one, should produce, by a kind of libration, the direct motion and the retrogradation. He therefore fixed the spheres of the planets at 26 in number.

Callippus, for his part, added no sphere at all for Saturn and Jupiter; but one each for Mars, Venus and Mercury themselves, and two each for the Sun and the Moon.

What his design was in doing so, all are silent. He therefore made the spheres of the planets 33 in number.

Aristotle, finally, added to each of the planets' spheres that did not follow the motion of the non-wandering stars as many others again, which he also called revolving spheres [Reuoluenteis], because they revolved the others back and made them conform to the motion of the non-wandering stars (except that for the Moon, as the lowest, he judged no revolving spheres necessary). And so, adding 22 over and above those of Callippus [Calippicis], he fixed the spheres of the planets at 55 in number, and the celestial spheres as a whole (with the primum mobile, or sphere of the non-wandering stars, added) at 56.

Since, among other things, it could not be said on this hypothesis why the planets are seen now larger, now smaller (for, their motion being concentric, the matter could not be explained by a lesser and greater distance from the Earth), Fracastorius [Girolamo Fracastoro] — who in the last century revived the concentrics, and called them "leading-around" [Circumducenteis], "going-around" [Circitores], "counter-going-around" [Anticircitores] and "carried-against" [Contravectos] spheres — judged; he judged, I say, that this could be saved by saying that the planets appear larger and smaller according to the condition of the parts of the heaven through which they pass, parts which so vary the refraction, like variously shaped glasses, as to induce such a variation in apparent magnitude.

I pass over the fact that he multiplied the spheres of the planets up to 63, assigning, namely, 4 to the Sun, 7 to the Moon, 9 to Mars, 10 to Saturn, and 2 [ij] each to Mercury, Venus and Jupiter; and that, besides the sphere of the non-wandering stars, he added 5 to vary its motions; and, moreover, the primum mobile; so that, in his view, the celestial spheres are 70 in number.

The hypothesis of eccentrics [Excentricorum] would indeed seem to be traceable to the Pythagoreans; but because they used it to explain the motion of the Earth, it seems, as far as the common opinion is concerned, quite certainly to have as its authors, first, Hipparchus, in so far as he could not bear that hodgepodge of homocentrics, and then, above all, Ptolemy, in so far as he set out the theoric of the planets by means of eccentrics.

CAPVT III.

Chapter 3.

Hypotheſis Ptolemaïca, ſeu communis, quæ eſt per Eccentricos, & Epicyclos.

The Ptolemaic, or common, hypothesis, which works by eccentrics and epicycles.

Ptolemy, indeed, was so moderate that he was content to describe the paths of the planets by eccentric circles. But because, as the opinion that the celestial spheres are solid gained strength, it was anxiously asked how their solidity could stand together with eccentricity, Georgius Peurbachius [Georg von Peuerbach], 200 years ago now, began to devise such spheres.

Let there be here some total sphere — for example, that of the Sun itself — which, the centre of the world, or of the Earth, being A, is concentric both in its outermost, or convex, surface B, C, D, E, which is surrounded by the sphere of Mars, and in its innermost, or concave, surface F, G, H, I, by which it surrounds the sphere of Venus. Let the point K be taken; and, from it as centre, conceiving elsewhere the Sun near the outermost surface, at L, let two circles be drawn that enclose it. It is clear, certainly, that the total orb will thus be divided into three partial orbs, such that the outermost and the innermost will be of unequal thickness, and the middle one between them, hollowed out as it were, of equal thickness.

Diagram. A woodcut of a total sphere divided into three partial orbs. A vertical line runs from B at the top to D at the bottom, and a horizontal line from C at the left to E at the right; the two lines cross at A. Working inwards: an outermost circle, at whose top, left, right and foot stand B, C, E and D; a hatched band, thin at the top and thick at the bottom; an unhatched ring of even width; a second hatched band, thick at the top and thin at the bottom; and an unhatched innermost circle. A dotted point K stands on the vertical line inside the innermost circle, above A.

- B (above the outermost circle, at the top of the vertical line)
- L (on the vertical line, inside the unhatched ring, at its top)
- F (on the vertical line, at the top of the innermost circle)
- K (on the vertical line inside the innermost circle, above A; the letter to the right of a dot)
- C (at the left end of the horizontal line, outside the outermost circle)
- N (above the horizontal line, inside the unhatched ring, left)
- G (below the horizontal line, at the left edge of the innermost circle)
- A (below the crossing of the two lines)
- I (above the horizontal line, at the right edge of the innermost circle)
- O (above the horizontal line, inside the unhatched ring, right)
- E (at the right end of the horizontal line, outside the outermost circle)
- H (on the vertical line, at the bottom of the innermost circle)
- M (on the vertical line, inside the unhatched ring, at its bottom)
- D (below the outermost circle, at the foot of the vertical line)

And because this middle orb is described wholly (that is, in its convex as well as its concave surface) from a centre other than that of the world itself, it is

therefore the one that is properly and simply called the eccentric; the other two, however, are called eccentrics in a qualified sense [ſecundum quid], in so far as they are eccentric only with respect to one of their surfaces: the outermost, namely, with respect to its concave surface, the innermost with respect to its convex.

Further, when the centres are joined by the line B D drawn through them, and the line C E is drawn at right angles to it [ad normam] and through the centre of the Earth, A, then the distance between the two centres, A K, is usually called the eccentricity [Eccentricitas]; the point L, which on the eccentric is farthest from the Earth, the apogee [Apogæum], and also the aux [Aux] and the highest apsis; the point M, which is nearest, the perigee [Perigæum], and also the opposite of the aux [Augis oppoſitum] and the lowest apsis; the line B D itself, or L M, the line of the apsides [linea Apſidum]; and C E itself, or N O, the line of the mean longitudes [linea Mediarum longitudinum] — as if to say that, while the Sun, moving along the eccentric L N M O, is removed farthest from the Earth at L and least at M, its removal at N and O is middling.

That is, they hold that the eccentric, since it is solid, revolves within those two unequal orbs, and that the Sun, bound or implanted in it, is carried round together with it. Moreover, that middle circle, which is conceived to be described by the centre of the Sun, is called the deferent of the Sun [Deferens Solem]; just as, of the thick orbs, the outer is called the deferent of the apogee [Deferens Apogæum], and the inner the deferent of the perigee [Deferens Perigæum].

Note, however, that out of this whole structure Ptolemy retains only the circle that is the deferent of the Sun; and that it is this circle which is properly understood and called the eccentric — namely, in so far as it is the path of the Sun. On the same principle, you have it in the following diagram, together with the eccentricity and the lines of the apsides and of the mean longitudes. But that outer and concentric circle is to be understood as representing the firmament [Firmamentum], or the outermost heaven.

Diagram. The Ptolemaic eccentric of the Sun drawn within its orbs: a set of shaded concentric rings and bands, with two bold circles, crossed by a vertical diameter and a horizontal diameter.

- B (above the top of the vertical line, where it meets the outer bold circle)
- L (just below B, left of the vertical line, at the top of the inner bold circle)
- K (near the centre, right of the vertical line, above the horizontal line)
- C (left end of the horizontal line)
- N (above the horizontal line, on the left, at the inner bold circle)
- A (below the horizontal line, just left of the vertical line)
- O (above the horizontal line, on the right, at the inner bold circle)
- E (right end of the horizontal line)
- M (below the bottom of the inner bold circle, right of the vertical line)
- D (below the foot of the vertical line, under the outer bold circle)

Let there also be another total sphere, for example that of Jupiter, divided like the one above into three orbs, and within the thickness of the eccentric simply so called [Eccentrici ſimpliciter] let a small circle PQRS be described. This small circle is what they call the epicycle [Epicyclum]. They hold that it is indeed moved together with the eccentric along the course LNMO, but that meanwhile it nevertheless revolves about its own centre L, and carries round the planet that is situated on its surface along the course PQRS.

Diagram. The Ptolemaic theory of a superior planet (Jupiter): heavily shaded outer and inner orbs, with light bands between them and a light central disc, crossed by a vertical diameter and a horizontal diameter. A small circle, the epicycle, sits on the vertical line at the top, cut by an arc, with a star mark on it.

- B (above the top of the vertical line, over the outer shaded band)
- P (inside the small circle at its top, left of the vertical line)
- ✶ (a star mark on the small circle, upper left)
- L (inside the small circle, right of the vertical line, at the arc that crosses the small circle)
- Q (left of the small circle, where the arc meets it)
- S (right of the small circle, where the arc meets it)
- R (at the foot of the small circle, right of the vertical line)
- F (at the top of the central light disc, left of the vertical line)
- K (below F, right of the vertical line, beside a dot)
- C (far left, outside the figure, at the level of the horizontal line)
- N (above the horizontal line, on the left)
- G (below the horizontal line, on the left, inside the central disc)
- A (below the horizontal line, just left of the vertical line)
- I or ı [?] (above the horizontal line, on the right, inside the central disc)
- O (above the horizontal line, on the right)
- E (far right, outside the figure, at the level of the horizontal line)
- H (at the foot of the central disc, right of the vertical line)
- M (below H, left of the vertical line, on a circle)
- D (below the foot of the vertical line, under the outer band)

Moreover, they call the highest point, P, the apogee of the epicycle [Apogæum Epicycli]; R, the lowest, its perigee; the points Q and S, the greatest elongations [Elongationes maximas]; and that circle LNMO, which the centre of the epicycle is conceived to describe, the deferent of the epicycle [Deferentem Epicycli].

Note here again that this circle is the one which alone Ptolemy retains, together with the epicycle that carries the planet, as you understand from this diagram, in which again the outer circle represents the firmament, or the highest heaven.

Diagram. An unlettered figure: a large circle, crossed by a vertical and a horizontal line; within its upper part a smaller circle; and at the top, on the

vertical line, a small circle (the epicycle) with a star mark, the planet, on its upper left. No letters are printed on the block.

I pass over, however, what he holds: that the same thing can be explained by a concentric with an epicycle as by the eccentric alone; and again, that it is easy to understand how a concentric with a double epicycle can explain the same thing as an eccentric [Excentricum] with a single epicycle — inasmuch as the very body of the planet appears always to keep the same path about the centre of the world (from which it comes, in just the same way, to stand now farther off, now nearer, now at a middling distance).

But indeed, so that the hypothesis may be set out according to the particular theories of the planets and of the firmament, somewhat more fully, and so that the phenomena that have been recounted may be explained more distinctly, come, let us touch briefly on each of the theories in turn.

CAPVT IV.

Chapter 4.

De Theoria Solis.

On the Theory of the Sun.

To make our beginning, then, with the Sun, as the prince and governor of the other luminaries [Luminum], let the first diagram of this kind be repeated.

Let A be the centre of the Earth, or of the world, from which

Diagram. The theory of the Sun: an outer circle with the signs of the zodiac set round it, and an inner circle displaced upward, its top at F; a vertical line from B to D and a horizontal line, with C and E above it; and several straight lines drawn across both circles through the points K and A near the centre.

- ♋ (outside the outer circle at the top, above B)
- B (just inside the top of the outer circle, left of the vertical line)
- F (at the top of the inner circle, left of the vertical line)
- ♌ (outside the outer circle, upper left)
- ♊ (outside the outer circle, upper right)
- N (on the outer circle, upper left, above and right of M)
- M (on the outer circle, upper left, below N)
- L (on the inner circle, upper left, where two lines meet it)
- ♍ (outside the outer circle, left, above the horizontal line)
- ♉ (outside the outer circle, right, above the horizontal line)
- K (above the centre crossing, right of the vertical line)
- ♎ (a sign outside the outer circle, far left, at the horizontal line)
- C (inside the outer circle, left, above the horizontal line)
- G (on the inner circle, left, above the horizontal line)
- R (inside the outer circle, left, below C)
- A (below the centre crossing, left of the vertical line)

- I or ı [?] (inside the inner circle, right, below the horizontal line)
- E (inside the outer circle, right, above the horizontal line)
- ♈ (outside the outer circle, far right, just below E)
- O (on the inner circle, lower right)
- H (at the foot of the inner circle, left of the vertical line)
- ♏ (outside the outer circle, lower left)
- T (on the outer circle, lower left)
- S (on the outer circle, lower left, below and right of T)
- ♓ (outside the outer circle, lower right)
- Q (on the outer circle, lower right, above P)
- P (on the outer circle, lower right)
- ♐ (outside the outer circle, lower left, near the foot)
- D (at the foot of the outer circle, left of the vertical line)
- ♑ [?] (below D, faintly printed)
- ♒ (outside the outer circle, lower right, near the foot) let there be described B C D E, representing the ecliptic in the first heaven (or, if you prefer, in the firmament), beneath which, and beneath the signs described on it, the Sun is moved with its annual motion. Let the eccentric — the circle described by this motion, a motion which is itself uniform — be the circle F G H I, and its centre K. Let the line of the apsides [linea Apſidum], which joins the centres, be drawn, B D; and let the eccentricity [Excentricitas] be A K, the apogee F, the perigee H; and let the line of the mean longitudes [linea Mediarum longitudinum] be drawn, C E, passing through the centre of the world, A.

With this laid down: since the Sun moves with a uniform motion along the eccentric, if our eye were at the centre K, it would undoubtedly observe the Sun moving uniformly beneath the ecliptic. But because it sees the Sun from A, the Sun therefore appears to it to move non-uniformly.

Let the Sun depart, for example, from the apogee F and arrive at L. Then an eye at K would see it as if occupying the place M on the ecliptic; but from the Earth itself it appears as if occupying N. Let it depart from the perigee H and arrive at O: from K it would be seen at P, but from A it is seen at Q; and so for the other places.

Further, the line K M, and any other line proceeding from the centre K to the ecliptic (such as K R, K S, etc.), is called the line of mean motion [linea Medij motus]; while the line A N, and any other drawn from the centre A to the same ecliptic (such as A C, A T, etc.), is the line of apparent, or true, motion [linea Apparentis, ſiue Veri motus].

That is, the mean motion is the usual name for the Sun's progress from the beginning of ♈, or the vernal equinox, up to the former line — for instance, the arc ♈ B M. The apparent, or true, motion is the same progress up to the latter line — for instance, the arc ♈ B N. And although it would be natural for the true motion to be called the same as the mean, astronomers are nonetheless accustomed to call it the apparent as well as the true motion. And so it comes

about that the point N, too, is called the true place of the Sun, and the point M the mean place of the Sun.

That difference between the mean and the true motion — namely the arc M N — is usually called the equation [Æquatio]; and also, by a word now become familiar, the prosthaphaeresis [Proſtaphæreſis], which means *addition* and *subtraction* together. For once the true motion has been obtained from observations, this difference must be now added to it, now taken from it, to derive the mean motion: added, while the Sun descends from the apogee to the perigee, because the true motion follows the mean; subtracted, while the Sun ascends from the perigee to the apogee, because the true motion precedes the mean. The opposite must be done when, the mean motion being had, the true is sought.

Meanwhile you see that when the Sun is at the apogee or the perigee, there is no prosthaphaeresis, because the two lines of the true and the mean motion then coincide; and that, on the other hand, the prosthaphaeresis is greatest when the Sun is at either of the mean longitudes, G or I; and that it is always the smaller, the nearer the Sun is to the apogee or the perigee.

I pass over the point that the arc intercepted between the apogee and the mean place of the Sun is the very thing commonly called the mean anomaly of the Sun [Anomaliam Solis mediam] (they also call it the argument [Argumentum]), while the arc intercepted between the apogee and the true place of the Sun is the true anomaly [Anomaliam veram].

I pass over also both that the apogee of the Sun (which is found at this time not far from the beginning of the seventh degree of ♋) advances with a very slow motion in the order of the signs [in conſequentia] (namely, by only three-quarters of one minute each year), and that the eccentricity itself is reckoned to be subject to variation — so much so that, although it is now found to be approximately the twenty-eighth part of the semidiameter of the eccentric, it is reckoned slowly, and up to a certain point, to increase and to decrease.

Note here that, since the ecliptic contains 360°, and the Sun does not run through it entire except in $365^{d}\ 5^{h}$ and approximately 49^{m}, the Sun therefore does not complete a whole degree each day in mean motion, but only 59′ 8″; whereas in apparent, or true, motion it completes at the apogee only 57′, and at the perigee 1° 1′ with a very few seconds.

CAPVT V.

Chapter 5.

De Theoria Lunæ.

On the Theory of the Moon.

It follows that we speak of the theory of the Moon, in which — and in the other planets that remain — attention must be paid not only to the motion in longitude but also to the motion in latitude.

Let us speak of the former first, and not concern ourselves with those thicker orbs. In the following figure, let A be the centre of the world; B C D E the ecliptic; F the centre of the eccentric (which is to be movable about the centre of the Earth); G N M O the eccentric itself; A F the eccentricity; F L the double eccentricity [Eccentricitas dupla]; G the apogee of the eccentric; M the perigee; G M the line of the apsides; C E, or N O, the line of the mean longitudes; P Q R S the epicycle of the Moon, whose centre is G; Q or R the Moon on the circumference [ſuperficie] of the epicycle.

Diagram. The theory of the Moon: an outer circle with the signs of the zodiac set round it, a horizontal line from C to E and a vertical line from B to D crossing at the centre A. A small circle is drawn about A, with F at its top. A larger circle passes through P and R at the top; the eccentric is marked at N and O on the horizontal line and at M at the foot. Five small circles are drawn at successive positions — at the top about G, upper left about X, left on the horizontal line about Y, lower left about θ, and at the foot of the figure — each with a crescent Moon marked on it; a line is drawn from A to T. Dotted circles and arcs run between the larger circles.

- ♋ (outside the outer circle at the top, above B)
- B (just inside the top of the outer circle, at the vertical line)
- T (small, on the outer circle at the top, left of B, where a line meets it)
- σ (small, on the outer circle at the top, right of B, where a line meets it)
- ♌ (outside the outer circle, upper left)
- ♊ (outside the outer circle, upper right)
- β (inside the outer circle, upper left, beside a line)
- α (inside the outer circle, left, below β, beside a line)
- ♍ (outside the outer circle, left, above α)
- ♉ (outside the outer circle, right, above the horizontal line)
- ☾ [?] (a crescent with a small letter beside it, just below B at the top of the upper small circle)
- G (at the centre of the upper small circle)
- P (at the left of the upper small circle, where it meets the larger circle)
- R (at the right of the upper small circle, where it meets the larger circle)
- S (at the foot of the upper small circle, on the vertical line)
- T (inside the larger circles, right, at the end of a line from A)
- μ (at the top of the small circle on the upper left)
- λ (at the left of the small circle on the upper left)
- X (at the centre of the small circle on the upper left)
- ☾ χ (a crescent and χ at the right of the small circle on the upper left)
- π (inside the outer circle, left, above the horizontal line)
- C (inside the outer circle, left, on the horizontal line)

- ♎ (a sign outside the outer circle, far left, at the horizontal line, printed turned)
- N (on the horizontal line, left, where the eccentric meets it)
- Y (at the centre of the small circle on the horizontal line, left)
- ☾ [?] (a crescent with a small mark beside it, at the right of the small circle on the horizontal line)
- F (at the top of the small circle about A)
- Z (right of the small circle about A, at a line)
- A (at the centre crossing, below the horizontal line)
- ε (right of A, below the horizontal line)
- K (below and left of A)
- η (below and right of A, on a line)
- L (below A, on the vertical line)
- M (on the vertical line, at the foot of the eccentric)
- O (right, on the horizontal line, where the eccentric meets it)
- V (right, on the horizontal line, near the outer circle)
- E (inside the outer circle, right, at the horizontal line)
- ♈ (outside the outer circle, far right, at the horizontal line)
- ρ (inside the outer circle, lower left, at the end of a line)
- ♏ (outside the outer circle, lower left)
- θ (at the centre of the small circle on the lower left)
- o or a drawn point-ring [?] (small, below the small circle on the lower left, at the end of a dashed line)
- ☾ ψ (a crescent and ψ at the lower right of the small circle on the lower left)
- ξ (below the small circle on the lower left)
- χ (inside the outer circle, lower right, on a line)
- ♓ (outside the outer circle, lower right)
- ☊, small (at the centre of the lowest small circle, on the vertical line)
- I (at the foot of the lowest small circle, left of the vertical line)
- ☾ (at the foot of the lowest small circle, right of the vertical line)
- ♐ (outside the outer circle, lower left, near the foot)
- ♒ (outside the outer circle, lower right, near the foot)
- D (at the foot of the outer circle, left of the vertical line)
- ♑ (below D)

A threefold motion must be attended to here. First, that of the apogee against the order of the signs [in antecedentia] (that is, from G towards T, V, etc.), uniformly about the centre of the world, each day

11° 12′, so that its period is completed within 32^{d} 3^{h} and about 5^{m}.

Second, that of the centre of the epicycle in the order of the signs [in conſequentia] (that is, from G towards X, Y, etc.), likewise uniformly about the centre of the world, 13° 11′ each day, so that its period is completed in 27^{d} 7^{h} 43^{m}; and this is properly what we called above the periodic month.

Third, that of the Moon itself on the epicycle — in the upper part against the order of the signs [in antecedentia] (that is, from P towards Q R), but in the lower part in the order of the signs (that is, from R towards S P) — uniformly about the point L, which is opposite the centre of the eccentric, 13° and about 4′ each day, so that its period is completed in 27^{d} 13^{h} and about 9^{m}.

When the centre of the epicycle is at the very apogee of the eccentric, G, while both stand under, for example, the beginning of ♋, where the Sun too is supposed to be, then — since the line of the Moon's mean motion is the one drawn from the centre of the world through the centre of the epicycle — the line of the motion of the apogee and the line of the mean motion will coincide in one. (Indeed, so too will the line of the true motion, if the Moon is at Q, since the line of the true motion is the one which, drawn from the centre of the world, passes through the body of the Moon itself.) And finally, so will the line of the Sun's mean motion, the Sun being, as it were, at B. I suppose, moreover, that the place of both the mean and the true motion of the Moon is reckoned, as with the Sun, from the beginning of ♈.

Let the apogee move from G to T, the centre of the eccentric having become Z; let the centre of the epicycle have arrived at X. Then A T will be the line of the apogee; A α the line of the mean motion; A β the line of the true motion; while the line of the Sun's mean motion, A B, will lie exactly midway between the lines of the apogee and of the Moon's mean motion. For although the apogee advances each day more slowly than the centre of the epicycle, by about two degrees, the Sun, running through about one degree each day in the order of the signs, takes that degree away from the motion of the centre of the epicycle and adds it to the motion of the apogee.

Note, however, that the degree by which the Sun advances each day as it follows the Moon is the reason why the Moon, on returning to the same point of its period, no longer finds the Sun there, but must still go on for two days and more in order to overtake it and meet it again. And so, while the periodic month is of 27 days and about a third, the synodic month comes to 29 days and a half, with very nearly three-quarters of an hour, as was already noted above.

Next, let the apogee also reach V, γ, δ, the centre of the eccentric having become ε, η, L; let the centre of the epicycle too have reached Y, θ, δ; and let the Moon, arriving at [?], have gone round the whole epicycle; and let the line of the Sun's mean motion, A B, always have gone on midway between, etc.

What I say about this half of the diagram is to be understood in the same proportion of the other half as well, although the epicycles are not drawn in it, nor likewise the lines and hidden circles [occultique circuli] marking the various positions of the eccentric, so that too much complication and confusion should not arise from it.

From this, meanwhile, one may gather that the centre of the epicycle always occupies the apogee of the eccentric at every mean conjunction and opposition with the Sun, and the perigee at the quadratures; and the remaining places at

the intermediate times, in proportion — so much so, accordingly, that it runs through the whole eccentric twice in a month.

Again, with the epicycle at X, the elongation of the Moon from the Sun is G X, and its double, or the distance of the Moon from the apogee, is T X. Whereas in the Sun this was called the anomaly, or argument, here it is usually called the centre of the Moon [Centrum Lunæ].

In this place, however, the argument is the name given to the distance of the body of the Moon itself — situated, for example, at κ — from the apogee of the epicycle, either the true apogee, which here is λ, or the mean, which here is μ (the latter is marked by a line drawn out from the point K, which is opposite the centre of the eccentric). Hence the former is called the true argument, and the latter the mean.

And while the arc λ μ is called the prosthaphaeresis, or equation of the centre, α β is called the equation of the argument. Whereas the former is added to the mean argument to obtain the true one if the centre of the Moon is less than six signs, and subtracted if it is greater, the latter, conversely, is subtracted if it is less and added if it is greater.

I need hardly say that the former is nil if the centre of the epicycle is at the apogee or perigee of the eccentric, and the latter nil if the Moon is at the apogee or perigee of the epicycle; and again, that the former is greatest a little below the mean longitudes, as ξ ο, the epicycle being at θ; and the latter is greatest when the centre of the epicycle is at the perigee of the eccentric and the Moon is at the point where the circumference of the epicycle is touched by a line drawn from the centre of the world, as C π, the epicycle being at Y.

I say nothing, too, of the fact that, since the diameter of the epicycle itself appears greater when it is at the perigee of the eccentric than at the apogee, as even the very difference shows between the arc of the zodiac πρ, which the diameter occupies at the perigee, and the arc στ, which it occupies at the apogee — and since a proportion, taken from elsewhere, is kept in the intermediate places, the whole variation is therefore usually divided into 60 small parts, which they call proportional minutes [ſcrupula, ſeu minuta proportionalia], so that, in proportion to the variation, what is fitting is added to the equation of the argument.

Finally, I say nothing of the fact that the body of the Moon itself — when, descending from Q through κ, φ, ψ, it has reached ι, and from there, in the same way, has returned through the other half to Q — is understood to have described not a circle but a kind of ellipse, or oval line. And these, then, are the principal heads concerning the motion in longitude.

As regards the motion in latitude, it is to be noted that, just as the path of the Sun, or ecliptic, intersects the equator obliquely at two opposite equinoctial points, so the orbit of the Moon, or the eccentric it describes, does not lie directly beneath the ecliptic but intersects it obliquely at two opposite points, which they call the nodes [Nodos]: the ascending node, at which the passage

is from south to north, and the descending node, at which it is from north to south.

And while this is common to the Moon and the other planets, it is peculiar to the Moon that the ascending node is drawn in this form, ☊, and the descending in this, ☋; and that the former is commonly called the Head [Caput], the latter the Tail of the Dragon [Cauda Draconis]. Perhaps this is because, as a dragon or serpent tapers towards its head and its tail and swells in the belly, so the space enclosed by half of the Moon's orbit and of the ecliptic tapers [?] towards the nodes and swells towards the middle, where the limit, or greatest digression, is [?] — as is understood from this figure.

Diagram. Two closed curves of nearly equal size, one set slightly above the other, cross each other at a point on the left and a point on the right. A node sign stands outside each crossing.

- ☊ (to the left of the left crossing): the ascending node
- ☋ (to the right of the right crossing): the descending node

Only two things, however, need to be noted here. The first: as the Moon, leaving a node, gradually acquires latitude until it has reached the northern or the southern limit, the greatest latitude, or distance, that it attains at either limit is 5°.

The second: the nodes are not fixed at definite points of the ecliptic but advance gradually against the order of the signs — each day, indeed, by a little more than 3′ — so that they complete their circuit within about 19 years. From this arises what we called above the Lunar Cycle, the Golden Number and the Period of Meton. For this reason, moreover, it is customary to imagine either an orb or a circle concentric with the world, which is called the deferent of the nodes [Deferens Nodos].

CAPVT VI.

Chapter 6.

De Theoria trium Superiorum Planetarum, nempe Saturni, Iouis, & Martis.

On the Theory of the Three Superior Planets, namely Saturn, Jupiter and Mars.

Since the motions of these three differ from one another not in form but in quantity alone, a diagram of the following kind suffices for all of them in general.

Diagram. The theory of the three superior planets: an outer circle with the twelve signs of the zodiac set round it, a vertical line from B at the top to D at the foot, and a horizontal line from C on the left to E on the right, crossing at the centre A. Further near-horizontal and oblique lines run through the centre, and two large circles are drawn within the outer one. Five small circles (epicycles) stand at successive positions — at the top, upper left, left, foot and lower right — several with a star marked on them.

- ♋ (outside the outer circle, top)
- ♌ (outside the outer circle, upper left)
- ♍ (outside the outer circle, left, above the horizontal)
- ♎ (outside the outer circle, left, at the horizontal line)
- ♏ (outside the outer circle, lower left)
- ♐ (outside the outer circle, bottom left)
- ♑ (outside the outer circle, bottom, below D)
- ♒ (outside the outer circle, bottom right)
- ♓ (outside the outer circle, lower right)
- ♈ (outside the outer circle, right, at the horizontal line)
- ♉ (outside the outer circle, right, above the horizontal)
- ♊ (outside the outer circle, upper right)
- B (just inside the outer circle at the top, on the vertical line)
- R (beside a star at the top of the upper small circle, right of the line)
- M (inside the upper small circle, on the line)
- G (below M, on the line)
- S (at the left of the upper small circle)
- Q (at the right of the upper small circle)
- T (below the upper small circle, on the line)
- α, Z, γ (inside the outer circle along the upper-left rim, from top to bottom; Z set slanting)
- Y, X, V (in the small circle on the upper left)
- β (beside a star at the lower left of the upper-left small circle)
- C (inside the outer circle at the left, on the horizontal line)
- N (at the upper left of the small circle on the left)
- H (inside the small circle on the left)
- [?] (a small sort like μ, beneath a star below the small circle on the left)
- L (above the centre)
- F (below L)
- A (at the centre, on the horizontal line)
- P (at the right, on the larger circle)
- K (below P)
- E (at the right end of the horizontal line)
- [?] (a sort like ε, to the right of a star on the vertical line near the foot)
- o (small, in the small circle at the foot)
- I (below o)
- D (at the foot of the vertical line, inside the outer circle)
- η (in the small circle on the lower right)
- [?] (a sort like ζ or ξ, beside a star below the lower-right small circle)

In this diagram, A is the centre of the world; B C D E the ecliptic; F the centre of the eccentric; G H I K the eccentric; L the centre of the circle called the equant [Æquantis], which stands as far from the centre of the eccentric as that centre does from the centre of the world; M N O P the equant itself, equal to the eccentric and in the same plane with it. This equant, whether an orb

or a circle, is introduced because the motions of planets of this kind in their eccentrics and epicycles are uniform, or regular, not about their own centres but about another's — namely, the centre of this equant. G is the apogee of the eccentric; I its perigee; M the apogee of the equant; O its perigee; B D the line of the apsides; C E the line of the mean longitudes; Q R S T the epicycle; G its centre; R the planet on the circumference [ſuperficie] of the epicycle.

Three motions, then, are considered here. The first is that of the apogee, in the order of the signs. This takes place not always beneath the ecliptic, as with the Sun, nor by approaching or receding from it, as with the Moon, but along a circle parallel to the ecliptic; so that it has indeed a different centre, yet the same axis; nor does it have any other period or irregularity than the one to be attributed to the ecliptic when we come to treat of the firmament.

The second is that of the eccentric — or, if you prefer, of the centre of the epicycle, G — in the order of the signs, that is, from B towards C, D, E. This takes place obliquely to the ecliptic and to the circle of the motion of the apogee, and it cuts their axis not at the centre but towards the perigee of the eccentric; so that the greater part of the eccentric, too, remains towards the apogee.

The daily motion, moreover, is, in Saturn, of minutes

2; in Jupiter, 5′; in Mars, 31 1/2′. And the whole circuit is completed, in Saturn, in 29 Egyptian years, 169 days; in Jupiter, in 11 Egyptian years, very nearly 316 days; in Mars, in 1 year, very nearly 322 days.

The third motion is that of the epicycle — or, if you prefer, of the planet on the circumference of the epicycle. In its upper part (unlike the Moon) it runs in the order of the signs, as, say, through Q, R, S; in its lower part, against the order of the signs, as, say, through S, T, Q.

Each day it amounts, in Saturn, to 57′; in Jupiter, to 54′; in Mars, to about 28′. And its period is completed, in Saturn, in 1 year and 13 1/4 days; in Jupiter, in 1 year and about 34 days; in Mars, in 2 years and about 60 days.

Let the centre of the epicycle be at V, and the mean apogee of the epicycle at X — marked, that is, by the line from the centre of the world. Then the line of the mean motion will be L Z, and the line of the true motion A α; the arc ♈ B Z will be the mean motion, and the arc ♈ B α the true motion. And since the line of the true place of the planet, standing at β, is A γ, the true motion of the planet will therefore be ♈ B γ.

Here too, moreover, the distance from the apogee of the eccentric is usually called not so much the anomaly or argument as the centre of the epicycle — and this either mean, as B Z, or true, as B α. Here, in addition, the distance of the planet from the apogee of the epicycle is specifically called the argument: the mean argument reckoned from the mean apogee, as the arc X β; the true argument from the true apogee, as the arc Y β.

I pass over the fact that here, in the same way, one takes the prosthaphaeresis [Proſtaphæreſin], or equation of the centre — namely, the arc α γ; and the proportional minutes, from the apparent variation in the diameter of the epicycle;

and the time at which the equations are either nil or greatest, and at which they are to be added or

subtracted, and anything else of this kind — all these, I say, are taken here in the same way as was explained for the Moon, as can be understood even from inspecting the diagram itself.

It must not be supposed, however, that when the epicycle, or its centre, has come from G to V, the planet has merely been carried across the surface of the epicycle from R or Y to β; and, when it has come to H, to δ; and, when to I, to ε. For before the epicycle of Saturn, for example, has come from G to I, the planet itself runs through the whole epicycle very nearly fifteen times. The planet has therefore been drawn in those places for this purpose only — and also at ζ, when the epicycle has come to η [?] — so that what has just been said may be understood; and also so that you may see how, when the epicycle has come to I, the planet can be at the perigee of the eccentric and of the epicycle at the same time.

What is remarkable here, meanwhile, is the agreement between the planet's revolution across the surface of the epicycle and the Sun itself. For such a revolution is completed in precisely as much time as passes from one mean conjunction, or mean opposition, with the Sun to the next. Thus at every mean conjunction the planet stands at the mean apogee of the epicycle, and at every opposition it is at the perigee. And so the planet is always as far from the mean apogee of the epicycle as the line of the Sun's mean place is from the line of the planet's mean motion; and consequently, if the planet's mean motion is subtracted from the Sun's mean motion, what remains is the planet's mean argument.

From this one may understand that the more slowly the centre of the epicycle goes round the eccentric, as in Saturn, the more quickly the epicycle, or the planet in it, revolves; the Sun that is, overtakes the planet sooner. And again, one may understand that the planet's mean motion, joined to its motion in the epicycle, equals the Sun's mean motion.

As for the latitude: it depends, indeed, on the obliquity with which the planet's orbit, or eccentric, stands to the ecliptic; but it happens nonetheless that the latitude is increased or diminished by the inclination and obliquation of the epicycle, which is not fixed but changeable and librating.

The greatest latitude, moreover, can scarcely reach — in Saturn, 2° and 5′ or 6′; in Jupiter, 1° and likewise 5′ or 6′; in Mars, finally, 7°.

CAPVT VII.

Chapter 7.

De Theoria duorum Inferiorum Planetarum, Veneris nempe, & Mercurij.

On the Theory of the Two Inferior Planets, namely Venus and Mercury.

We consider these two together as well, because of the form of motion they share, in which they differ from the three already mentioned.

First, then, both an eccentric and an epicycle belong to these two also; but the line of their mean motion never departs from the line of the Sun's mean motion. Rather, it is so entirely one and the same with it that the centres of the epicycles are, as it were, tied to the line of the Sun's mean motion; and consequently the planets cannot wander farther from the Sun than their epicycles themselves allow — quite unlike the superior planets, which, because their lines of mean motion are different, even as far as the very opposition with the Sun, move away from the Sun.

From this, meanwhile, it is clear that they have no mean motion in longitude other than the Sun's; that by reason of this motion they are always in conjunction with the Sun; and that, consequently, each of them runs through its eccentric [Excentricum] in the same period, namely one year. All of this can be understood even from mere inspection of this figure.

Diagram. A large circular figure filling the rest of the page. An outer circle carries the twelve signs of the zodiac set outside it; inside it stands a second solid circle, and inside that two dotted circles, a larger and a smaller. A vertical line runs from the top of the figure to the bottom. Two horizontal lines cross the figure: the upper one meets the vertical line at the point from which two straight lines run out to the left, one rising towards ♍ and one falling towards ♏; the lower one runs from the sign at the left to ♈ at the right. Along each of four lines — the vertical line above and below that point, the rising line and the falling line — sit three small circles: one on the second solid circle, and two farther in, each of these carrying a six-pointed star on one of the dotted circles. No letters are printed on the figure.

- ♋ (outside the outer circle, at the top): Cancer
- ♊ (outside the outer circle, upper right): Gemini
- ♉ (outside the outer circle, right, above ♈): Taurus
- ♈ (outside the outer circle, at the right, at the end of the lower horizontal line): Aries
- ♓ (outside the outer circle, lower right): Pisces
- ♒ (outside the outer circle, lower right, below ♓): Aquarius
- ♑ (outside the outer circle, at the bottom): Capricorn
- ♐ (outside the outer circle, lower left): Sagittarius
- ♏ (outside the outer circle, left, below the sign at the left): Scorpio
- ♎ [?] (outside the outer circle, at the left, at the end of the lower horizontal line): Libra [?]
- ♍ (outside the outer circle, left, above the sign at the left): Virgo
- ♌ (outside the outer circle, upper left): Leo

They agree with the superior planets, again, in that in the upper part of the epicycle they move with the succession of the signs, and in the lower part against it. They agree, again, in that they have in the epicycle itself an apogee both mean and true, from which the argument, both mean and true, is taken

or counted as far as the bodies of the planets themselves; and, by the same reasoning, the prosthaphaeresis, or equation, both of the centre and of the argument, is used, with the proportional minutes also applied. But they differ in that, while they are not only at the apogee but also at the perigee, they are in conjunction with the Sun itself — as can be understood even from the same figure used just now.

As for the rest: the theory of Venus is no different from the theory of the three superior planets, since it consists of the same orbs, namely the eccentric, the epicycle and the equant. One may therefore use the same figure that was used for them, provided only that we conceive the line of the Sun's mean motion to be carried along with it and always to pass through the centre of the epicycle.

The theory of Mercury, by contrast, differs only in this: between the two thick orbs — or eccentrics in a qualified sense [Eccentricoſve ſecundum quid] — they conceive two others, likewise unequal; between those two they place the equant; and between these two, the deferent of the epicycle, or eccentric properly so called [Eccentricicum] [recte: Eccentricum], whose movable centre lies on the surface of a small circle which with its diameter touches the centre of the equant and the centre of the world. This is almost the same way as was explained for the centre of the Moon's eccentric, carried round on the surface of a small circle; so that no new figure seems to be needed here either.

I pass over, further, the point that the motion of Venus in the epicycle is 1° 36′ a day, and that its whole period is consequently completed within very nearly 225 days, or 7½ months; even though, because of the Sun's progress in the meantime, it does not appear to us in conjunction again at the apogee, or again at the perigee, except after 19 months.

As for Mercury, on the other hand, I pass over that its motion in the epicycle is 4° 5′ [÷] a day, and that its period is completed within very nearly 88 days, or nearly three months; even though it returns from one apogeal conjunction with the Sun to another apogeal one, or from a perigeal one to a perigeal one, only after about 4 months.

As for the motion in latitude: it too arises partly from the obliquity of the eccentric and partly from the inclination of the epicycle; and indeed from such a tempering of the two that in Venus the greater latitude is to the north, and in Mercury the greater is to the south. In Venus, indeed, the latitude sometimes reaches 9°, but in Mercury not more than five.

CAPVT VIII.

Chapter 8.

De Theoria Firmamenti, & ſuper-exſtructi vnius, alteriuſ-ve Cryſtallini.

On the Theory of the Firmament, and of the One Crystalline, or the Second, Built above It.

Finally, so that we may also touch on a few points about the firmament, and at the same time explain the phenomena that have been reported about it: it must be understood, first of all, that as long as no motion had been observed around the fixed stars apart from the daily one, the firmament, to which the fixed stars are attached, was held to be the outermost heaven, or the primum mobile — as it was in Aristotle's age and in the centuries that followed, down to Hipparchus and Ptolemy. But from the time when the fixed stars themselves were also found to move forward in the order of the signs, a ninth heaven then began to be added, which would be the primum mobile and to which the daily motion would properly belong; and the firmament was held to be the second mobile [Secundo mobili], whose special motion would be that motion in the order of the signs. The reason, of course, is that two motions in their own right were believed not to belong to a single movable body, as we touched on above.

Further, this motion was noted to proceed unevenly, and even, according to some, to be sometimes retrograde; and it has been observed from another source that the ecliptic changes its position along with the fixed stars in such a way that its obliquity, and so the Sun's greatest declination, turned out now greater, now smaller. (It was greatest in Ptolemy's time, or a little before, namely 23° 52′; it then decreased in such a way that in the last century, when it was believed to be at its least, it stood at 23° 28′.) For that reason a tenth heaven began to be added above, which would be the primum mobile; and at the same time the ninth heaven was retained — called by most the Crystalline — to which that motion in longitude, or in the order of the signs, would be attributed. To the firmament itself, however, was assigned the motion that the Alphonsines in particular called the motion of access and recess, and of trepidation.

That is to say: having assigned an immobile ecliptic to the primum mobile, and likewise to the ninth sphere, they made the ecliptic of the firmament itself variable, or so displaced on the surface of two small circles de- scribed about the equinoctial points, that a twofold irregularity of this kind would arise from it. The matter is explained laboriously; but so that we are not entangled in so many complications — and especially in a matter that perhaps does not rest on a very firm foundation — let us try merely to grasp it from the small circles shifted, for the sake of ease, to lie about the solstitial points themselves.

In the following figure, let ABCD be the colure of the solstices [Colurus Solſtitiorum] in the ninth sphere; A and C the beginnings of ♋ and ♑ in that sphere; EFGH and IKLM the small circles drawn around them; E and I the beginnings of ♋ and ♑ in the eighth sphere,

Diagram. A large circle, with B above its highest point and D below its lowest point. A straight horizontal line crosses the whole figure through the

middle. On each side the large circle passes through a small circle that the horizontal line bisects. Two straight lines, from K to H and from M to F, cross each other and the horizontal line at one point in the middle of the figure, marked with a dot and carrying no letter; a further small dot, also unlettered, stands above that point, level with K and F.

- B (above the highest point of the large circle)
- D (below the lowest point of the large circle)
- L (outside the left small circle, at the left end of the horizontal line)
- K (above the left small circle, where the large circle meets it at the top)
- M (below and left of the left small circle, where the large circle meets it at the bottom)
- C (inside the left small circle, below the horizontal line, just left of where the large circle crosses that line)
- I (at the right edge of the left small circle, above the horizontal line)
- E (outside the right small circle, at the right end of the horizontal line)
- F (above and right of the right small circle, where the large circle meets it at the top)
- H (below and right of the right small circle, where the large circle meets it at the bottom)
- A (inside the right small circle, below the horizontal line, just right of where the large circle crosses that line)
- G (inside the right small circle at its left edge, above the horizontal line)

while the ecliptic of each sphere coincides, and the obli- quity is least. Let the point E be understood to proceed towards F, to the north, and the point I towards M, to the south; then the obliquity will also increase until it is greatest at F and M, and the ecliptic of the eighth sphere, having moved farther forward towards the east, becomes F M. Let the same points be understood to proceed from F to G and from M to L; then the obliquity will also decrease until it is least, and the ecliptic of the eighth, having moved still farther forward towards the east, comes together with the ecliptic of the ninth. Let the same points be understood to go on from G to H and from L to K; then the obliquity will increase again until it becomes greatest at H and K, and the ecliptic of the eighth, having gone back towards the west, becomes HK. Let the same points be understood, finally, to go on from H to E and from K to I; then the obliquity will decrease again until it becomes least, and the ecliptic of the eighth, having gone back still farther towards the west, comes together again with the ecliptic of the ninth.

All this, indeed, works in such a way that, while the ninth sphere moves the ecliptic of the eighth continuously and uniformly towards the east, the ecliptic of the eighth itself nevertheless, by this displacement of its own, renders a motion of this kind irregular. It makes the motion faster when both motions conspire towards the east — the points already mentioned proceeding, that is, through the halves EFG and IML of the small circles — but slower when one

of the two motions is towards the west, the same points, namely, proceeding through the opposite halves GHE and LKI.

Finally, however, it was decided to make two heavens out of that ninth heaven, and to relegate the primum mobile itself to the eleventh place; and indeed, to the firmament itself, the motion in longitude, as proper to it,

to restore; but to divide the motion of trepidation into two librations, of which one, from west to east and from east to west, would be attributed to the ninth sphere, and the other, from north to south and from south to north, to the tenth. In this way the former would make that motion in longitude now faster, now slower; and the latter would make the obliquity now greater, now less.

Accordingly, that motion in the order of the signs, or motion in longitude, is now usually attributed to the firmament; ever since Copernicus it has been called the precession, or anticipation, of the equinoxes [Præceſſio, ſeu Anticipatio Æquinoctiorum]. The reason is that Copernicus, because of the motion attributed to the Earth, held not so much that the stars pass beyond the motionless equinoxes, tending towards the following signs, as that the equinoxes themselves leave the motionless stars behind, tending towards the preceding signs. To the ninth sphere, too, is usually assigned the libration that is therefore called the anomaly of the precession of the equinoxes [Anomalia Præceſſionis Æquinoctiorum], because it makes the motion of the precession of the equinoxes unequal; and finally, to the tenth is usually assigned the libration that is called the anomaly of the obliquity of the ecliptic [Anomalia Obliquitatis Eclipticæ] for this reason, that it does not allow the obliquity of the ecliptic to be always the same.

Now the motion of the firmament, or the eighth sphere, is carried out very slowly on the poles of the ecliptic. According to Ptolemy, indeed, it does not complete one circuit except within 36,000 years, completing, that is, only one degree within a hundred years; although the passage of time has taught us that it completes it rather within very nearly 25,000 years, finishing, that is, one degree within 70 years; even though, on other grounds,

the Alphonsines held that it does not complete a circuit except within a thousand jubilees, or 49,000 years.

The motion of the ninth sphere, for its part, takes place on the same poles; not, however, by completing a circuit, but only by librating gently. For after the sphere has advanced towards the east through two degrees and a third, that is, 1° 10′ on this side of the equinoctial points and 1° 10′ beyond them, the return is made from east to west; and this too very slowly indeed. For one libration, going and returning, is completed only within 1700 years.

Finally, the motion of the tenth sphere, which has the equinoctial points themselves as its poles, so to speak, is carried out along the solstitial colure, with a libration smaller still: namely through not more than 24′, of which 12′ are on this side of and 12′ beyond the solstitial points, these being taken as if fixed in

the primum mobile itself. The libration is, moreover, twice as slow, since one libration is run through only within three thousand and 400 years.

Small circles are indeed described here too, to explain how the librations appear faster towards the middle and slower towards the beginning and the end. But, as will be noted at the point where we touch on how Copernicus explained the matter, the thing seems to be more a fiction than something for us to pursue more scrupulously.

CAPVT IX.

Chapter 9.

Quare Planetæ nunc Majores, nunc Minores appareant.

Why the Planets Appear Now Larger, Now Smaller.

Now, how those phenomena that were mentioned at the beginning, and that for the most part are commonly called the passions of the planets [Paſſiones Planetarum], are explained from the hypothesis and the theories already reviewed is not at all difficult to say.

First, indeed, I pass over those that are understood amply enough from what was deduced in the previous book. Of this kind are: that the Sun and the other planets are observed to rise and set now here, now there; to be carried up to the meridian now higher, now lower; that the rest are now hidden by the Sun's brightness, now revealed; and other similar things.

To touch on the rest: it seems, first of all, nothing to wonder at if the planets sometimes appear larger, sometimes smaller. For since at their apogees they are far more distant from the Earth than at their perigees, they must be represented there under a smaller appearance, and here under a larger.

There is no need to point out that the question here is not about the appearance that grows near the horizon because of vapours, and that shrinks as the stars are raised on high. For here we are dealing with the appearance that a planet presents at the same altitude above the horizon, the meridian altitude included.

In the superior planets, indeed, the matter is easy to observe and quite evident. For whenever they are opposite the Sun, they appear largest for this reason, that in

the perigees of the epicycles they stand; not to mention that their appearance grows larger still, the more the epicycle approaches the perigee of the eccentric. Mars in particular, certainly, which is otherwise scarcely equal to a star of the second magnitude, nevertheless at opposition, or while it is acronychal [Acronychus], and especially when both perigees coincide, takes on such an appearance that it rivals the size of Jupiter and of Venus.

The matter is easy, too, in the two inferior planets, that is, Venus and Mercury, but in Venus most of all, since towards the perigee it is easily seen even by day, and right at noon itself. Why, however, it is not seen in the same

way when it is towards the apogee, although its appearance by night does not appear to be smaller, is to be understood from what will be said below, in the passage on its horns.

With the Moon the matter is a little more difficult. We ourselves, however, have observed its diameter, when it is at perigee in both the eccentric and the epicycle, to be 31′ 6″; and when at apogee, 26′ 36″, even though others do not bring it down to so small a size.

With the Sun it is most difficult; but we ourselves have nevertheless observed its diameter too: when it is perigean, 31′ 6″, just as much, namely, as that of the Moon itself; and when apogean, 30′ 12″; so that there is plainly not a whole minute of difference at all.

CAPVT X.

Chapter 10.

Quare nunc Veloces, nunc Tardi.

Why Now Fast, Now Slow.

By the same reasoning it is no wonder if the planets appear to advance now more quickly, now more slowly. That is: although they themselves move with a uniform motion in their eccentrics and epicycles — as they would also appear to us to move if, as has been said, we were at their centres — we must nevertheless observe them to be carried non-uniformly, because we view their motion from a centre not their own.

Hence in the Sun, for example: the line of the mean longitudes, which divides the ecliptic for us into two equal parts, cuts the eccentric in such a way that the portion of it towards the apogee is larger than the portion towards the perigee. For that reason the Sun must appear to us to run through one half of the signs in a longer time than the other; and on that account to advance more slowly at one time than at another, and so to be carried non-uniformly — most slowly, indeed, at the apogee, most swiftly at the perigee.

And since in our times the Sun's apogee lies, as we have already touched on, at the beginning of the seventh degree of Cancer, and the perigee accordingly at the beginning of the seventh degree of Capricorn, the reason is plain why that portion of the year which runs from the vernal equinox to the autumnal, passing through summer, is nine days longer than the portion from the autumnal to the vernal, passing through winter.

Namely, the portion of the eccentric to be run through in the former is greater than in the latter.

And this is why, although the Sun is observed at the intermediate times to cover 59′ a day by its apparent motion, at the apogee it nevertheless covers only 57′, and at the perigee 61′, as was also noted above.

With the Moon the case is otherwise. For since the centre of the epicycle moves uniformly not about the centre of the eccentric but about the centre of

the world, which always lies towards the perigee, that centre must appear to be carried faster at the apogee of the eccentric than at the perigee: there, namely, larger portions of the eccentric correspond to equal arcs of the zodiac than here. The same is to be said, proportionally, of the Moon's motion in the epicycle, inasmuch as it moves uniformly not about its own centre but about a point that is opposite to the centre of the eccentric itself.

From this, moreover, comes the reason why, although the Moon is at apogee both at conjunction and at opposition with the Sun, it nevertheless appears to move faster then than when it is at perigee in the quadratures.

It is also the reason why, although with its mean motion the Moon appears to cover about thirteen degrees a day, it nevertheless sometimes appears to cover not quite eleven, and sometimes more than fifteen.

With the other planets the account is different from that of the Moon. For although they move uniformly not about the centres of the eccentrics but about the centres of the equants, these centres of the equants nevertheless lie, with respect to us, or to the centre of the world, beyond the centres of the eccentrics; and

therefore they must appear to move more slowly about the apogees than about the perigees.

CAPVT XI.

Chapter 11.

Quare nunc Directi, nunc Retrogradi, nunc Stationarij.

Why Now Direct, Now Retrograde, Now Stationary.

This condition belongs only to the five wandering stars, inasmuch as they are found in various parts of their epicycles.

For in the upper part of the epicycle the planet imitates the motion of the eccentric itself, or of the epicycle's centre, which is always in the order of the signs. Hence it comes about that by this doubled motion the planet is, as it were, made direct, or directs its course according to the series of the signs — most swiftly, indeed, through the apogee itself, but on either side of it the more slowly, the farther it is from it.

And since in the lower part it runs counter to the motion of the eccentric, and is carried through the epicycle against the order of the signs faster than it is carried along by the eccentric in the order of the signs, it comes about that it appears to go backwards, or to move contrary to the succession of the signs — most quickly, indeed, through the perigee itself; on either side, the more slowly, the farther it is from it.

Finally, in the descending or eastern part of the epicycle, at the part where from direct it becomes retrograde, and in the ascending or western part, where from retrograde it becomes direct, it seems to stick fast and to occupy the same

place among the fixed stars for some time. Hence it is said, at both places, to stand still, or to become stationary; and in

the descending part it is said to be at the first station, but in the ascending part at the second station; while in Venus and Mercury the former is moreover called the morning station, the latter the evening station.

At that time, indeed, the planet moves uniformly through the epicycle, just as at other times; but the eye nevertheless does not perceive its progress, because the motion then takes place, with respect to the eye, along a line that is, as it were, straight and stretched out from the eye itself, and not along a transverse course by which it could on that account be noticed.

The stations, however, do not occur at the planet's greatest elongations from the Sun themselves, which are marked by two lines drawn from the eye, or from the centre of the world, and touching the epicycle on either side, but below them. From this it follows that the arc of retrogradation is always smaller than the arc of direction; since, for another reason as well, the arc of retrogradation is the shorter, the more the motion of the eccentric takes away from the motion of the epicycle, and the arc of direction the longer, the more the motion of the eccentric adds to the motion of the epicycle.

To understand all this, one need only attend to the diagrams given in the theories of the wandering stars themselves; or else simply look at this one, in which the centre of the world, or the spectator's eye, is A; the zodiac, in the order of the succession of the signs, BCD; the eccentric EFG; the epicycle EHGI; the tangents, or lines of the greatest elongations, AB, AD; the arc of direction EHG; of retrogradation [Retrogadationis] [recte: Retrogradationis] GIE; the first station K; the second station L.

Diagram. A woodcut of three circles and three straight lines, set at the head of the page above the text. A large outer circle, drawn whole, encloses the figure. A middle circle, also drawn whole, lies inside it; its top arc passes through G, F and E. A small circle straddles the top of the middle circle, with its centre near F. A vertical line runs from A at the bottom up through I, F and H to C at the top. Two straight lines run upward from A, one to D and one to B, each touching the small circle on its own side. A small unlabelled cross-tick stands on the vertical line a little above A.

- C (above the outer circle at the top, on the vertical line)
- D (upper left, outside the outer circle, at the end of the left slanting line)
- B (upper right, outside the outer circle, at the end of the right slanting line)
- H (inside the small circle, at its top, on the vertical line)
- F (inside the small circle, just above the arc of the middle circle, left of the vertical line)
- G (left of the point where the middle circle meets the small circle on the left)
- K (just right of and below G, inside the small circle, beside the left slanting line)

- L (inside the small circle on the right, above the arc of the middle circle)
- E (right of the point where the middle circle meets the small circle on the right)
- I (at the bottom of the small circle, on the vertical line)
- A (at the lower end of the vertical line, where the two slanting lines meet)

Meanwhile, from what has just been said, and from what we touched on earlier about the motions of the individual planets both in the eccentrics and in the epicycles, it is understood to come about that, of the three superior planets, Saturn retrogrades only 7 degrees, or somewhat more; Jupiter only 10; Mars at most 20 (for sometimes only 12). Of the two inferior planets, Venus retrogrades about 16 or 17; Mercury sometimes as much, sometimes about eleven.

I pass over, however, the fact that, since in these two the conjunction with the Sun is midway between the two stations, in those

three the opposition is midway; and that while the stations are taking place, Saturn is distant from the Sun by more than a quadrant of the circle, Jupiter by a third [triente], and Mars by more than a third.

Besides, too, whereas of those two there are more stations of Mercury than of Venus — because, running through its epicycle far more quickly, Mercury comes more often to this side and that of the Sun — of the three superior planets it is the other way round: there are more of Saturn than of Jupiter, and more of Jupiter than of Mars. For since Saturn is slower than Jupiter, the Sun overtakes it more quickly; and by the same reasoning, since Jupiter is slower than Mars, the Sun also overtakes it more quickly.

I said, further, that this property belongs only to the 5 wandering stars. For the Sun does not move through an epicycle, but only through an eccentric [Eccentricicum] [recte: Eccentricum]; in it, accordingly, the Sun can indeed appear to move more slowly at one time than at another, but not on that account ever to retrograde or stand still. The Moon, on the other hand, does move through an epicycle, and in its upper part against the succession of the signs. But the motion of the eccentric (that is, of the centre of the epicycle through the eccentric) is much swifter than the motion of the Moon through the epicycle, and for that reason the Moon, even then, is carried forward by the eccentric in the order of the signs [in conſequentia] faster than it is carried back through the epicycle against the order of the signs [in antecedentia]. Hence it comes about that the Moon appears to move more slowly, indeed, but not on that account to stand still or to go back.

CAPVT XII.

Chapter 12.

Quid Parallaxis, ob quam Planetæ altiores, aut humiliores iudicantur.

What Parallax Is, on Account of Which the Planets Are Judged Higher or Lower.

By the name of parallax [PARALLAXEOS] is understood here not just any change, but the change of sight [commutatio Viſus], which is also called the aberration of sight [Viſus aberratio] and the diversity of aspect [Adſpectus diuerſitas]; and it is usually described as the difference between the true and the apparent place of some star.

The true place of a star, further, is the point in the firmament, or highest heaven, at which a straight line drawn from the centre of the Earth, or of the world, through the very centre of the star ends. The apparent place, by contrast, is the point in the same heaven at which a straight line drawn from the eye through the same centre of the star ends. Hence also, because these two points fall in the same vertical circle, parallax is also usually defined as the arc of the vertical circle intercepted between the true and the apparent place.

Let, for example, A be the centre of the Earth, or of the world; C B D the surface of the Earth; B the eye; E F G a vertical circle in the firmament, or highest heaven. Let the star first be on the sensible horizon at H. Then the true place will be I, the point, namely, at which the line A I ends; the apparent place K, the point, that is, at which the line B K ends; and the arc I K the parallax — that is, the difference between the two places.

Diagram. A woodcut half-figure set at the head of the page, standing on a straight base line E–G. Centred on the foot of the vertical line at A are a small half-circle (from near C to near D), two larger half-circles (called here the third and the second circle, counting inward from the outer), and an outer half-circle running from E up through F to G. A vertical line rises from A through B and R to F. A horizontal line runs from K through H and S to B, and on to the outer circle on the right. A fan of straight lines runs from A and from B up to the left, reaching the outer circle between K and Z. Eight six-pointed stars stand on the circles: at H, S, L, V, O, Y and R, and one more, unlabelled, where the vertical line meets the third circle.

- F (above the outer circle at the top, on the vertical line)
- Z (on the outer circle, upper left, right of P)
- P (on the outer circle, upper left, between Q and Z)
- Q (on the outer circle, upper left, left of P)
- X (outside the outer circle on the left, below Q)
- M (outside the outer circle on the left, below X)
- N (outside the outer circle on the left, just below and left of M)
- T (outside the outer circle on the left, below N)
- I (outside the outer circle on the left, below T)
- K (outside the outer circle on the left, below I, at the left end of the horizontal line)
- H (below and right of the star where the horizontal line meets the second circle on the left)
- E (left of the left end of the base line)
- S (above the star where the horizontal line meets the third circle on the left)

- L (left of a star on the second circle, above H)
- V (above and right of a star on the third circle, above S)
- O (left of a star on the second circle, above L)
- Y (above and right of a star on the third circle, above V)
- R (left of the star where the vertical line meets the second circle)
- B (right of the vertical line, just above the horizontal line)
- C (below the base line, left of A)
- A (below the base line, at the foot of the vertical line)
- D (below the base line, right of A)
- G (right of the right end of the base line)

But if the star is next raised to L, it is plain that its parallax will be M N; if to O, that the parallax will be P Q; and so for the other places.

Note here, meanwhile, that the horizontal parallax is the greatest, and that as the star rises the parallax decreases in such a way that, if the star reaches the vertex R, there will in the end be no parallax at all: for the lines of the true and the apparent places come together into one, so that the true and the apparent place will be the same.

It may also be noted, moreover, that the nearer a star is to the Earth, the greater the parallax produced for it. For a star at S, for example — that is, on the same horizontal line as H — produces the parallax T K; at V — that is, on the same line of the true place as L — it produces the parallax N X; at Y — that is, on the same line as O — it produces the parallax Q Z.

Indeed, one must also note that the angle formed at the centre of the planet by the lines of the true and the apparent places, and opposite which the Earth's semidiameter lies — such as, for example, the angle A H B, or A L B, etc. — is properly the one that is both called the angle, and is the measure, of the parallax. That is, according as this angle is large, or small, or nil, so the arc called the parallax is likewise large, small, or nil.

I pass over, further, the fact that there is another kind of parallax, which is considered in the Moon and which occurs both in longitude and in latitude. This kind, namely, is considered not in the vertical circle, but either in the ecliptic itself — which the circles of latitude of the true and the apparent places cut at different points, intercepting the arc called the parallax of longitude [Longitudinis Parallaxin] — or in a circle at right angles to the ecliptic, which is cut by two circles drawn through the true and the apparent places and parallel to the ecliptic; these intercept the arc that is called the parallax of latitude [Parallaxis Latitudinis].

CAPVT XIII.

Chapter 13.

Quæ ſit proinde ſingulorum, & Fixarum etiam, à Terris diſtantia: quiſque adeò Cœlorum ordo.

What, accordingly, is the distance from the Earth of each one, and of the fixed stars too; and so what the order of the heavens is.

Since the greater the parallax, the nearer the thing seen is, and the smaller, the more distant, astronomers therefore set themselves to observe whether the stars have parallaxes, and how great they are, so as to pronounce on their nearness to, or remoteness from, the Earth.

And indeed, although in the Moon itself the parallax becomes quite perceptible (the horizontal parallax, that is, exceeds even a whole degree), in the others the matter is nonetheless so delicate a business that it does not go beyond probability.

For in Mercury, Venus, the Sun and Mars a parallax is detected only with the greatest difficulty; in Jupiter and Saturn there is scarcely any; and as for the fixed stars, they are raised far too high to betray any at all.

I do not stop to mention that the cause of this is the one we hinted at above: namely, that the Earth's semidiameter — which is taken both as the common measure and, as it were, as the interval between two measuring stations — bears a perceptible ratio to the distance of the Moon, but to the distance of the others so slight a one that it almost, or even entirely, vanishes; as though the Earth were by now like a point, and it made no difference whether a star is viewed from the Earth's surface or from its centre.

Still, in order to set out at this point the distance of the stars which, following Ptolemy's view, al-Battānī [Albategnius] above all, and al-Farghānī [Alphraganus], deduced, and which others have adopted: since that distance is expressed in multiples of the Earth's semidiameter, we must touch briefly on how large the Earth's semidiameter is.

Since, then — although opinions about the circumference of the Earth vary — it is nearly established for us that the Earth measures 26,255 Italian miles, because in a great circle on the Earth's surface very nearly 73 miles correspond to one degree, for that reason the Earth's diameter will be 8354 Italian miles, and its semidiameter 4177 miles.

I assume, moreover, as a commonplace, that a mile is so called because it contains a thousand paces (or 8 stadia, each of which is 125 paces); and that the pace meant is the geometric pace (or double the common pace), containing, that is, five feet; and that the foot meant is likewise the geometric foot — one, indeed, that is smaller than the Paris foot, also called the royal foot, by very nearly one tenth part. For, dividing the Paris foot into a thousand small parts, we found that the ancient Roman foot contains nine hundred and four of them.

I use the Italian mile, however, rather than the French league, because it is a more constant measure. Even so, since the average French league contains more or less three Italian miles, nothing prevents reducing the measures given

so that the circumference of the Earth is reckoned to contain 8752 French leagues, the diameter 2785, and the semidiameter 1392.

Be that as it may, here is the distance which those Arabs deduced from Ptolemy's principles, not only for the Sun and the Moon, but also for the five wandering stars, and for the sphere of the fixed stars too. In the planets themselves, however, the distance to be understood is the mean distance, or the one taken when they are moving about the mean longitudes; for otherwise they are farther away in the apogee and nearer in the perigee.

Mean distance at which they stand from the Earth	in semidiameters of the Earth
Moon	49
Mercury	115
Venus	618
Sun	1165
Mars	4584
Jupiter	10423
Saturn	15800
Fixed stars	19000

Meanwhile, from the very series in which these distances increase, the order of the heavens set out in the Preliminaries [Proœmialibus] of this Institution stands confirmed — at least as far as the heaven of the fixed stars; for what can be said about the rest we touched on in connection with the theory of the firmament.

Some other reasons besides parallax are, indeed, customarily brought forward to confirm this order; but these either are deceptive, like the one drawn from shadows (for it is false that a shorter shadow is cast by a more distant luminous body, if it is taken at the same altitude above the horizon — that is, at the same degree — as the nearer one), or, being drawn from fitness, are not equally persuasive: as when they declare it fitting that the Sun, being the chief of all, should hold the throne in the middle.

This reason certainly moved neither Plato nor Aristotle, who placed the Moon in the lowest place and the Sun in the next one. Nor, likewise, did it move Anaximander, or Metrodorus of Chios, who had the Sun in the highest place, the Moon in the next, the wandering stars in the places following, and the non-wandering stars in the lowest. Nor, likewise, others, who assigned now these seats, now those, to the Sun and to the rest.

And it would indeed seem that we ought to say at this point in what way it is probable that Mercury and Venus are carried round the Sun so that they are sometimes lower and nearer, but sometimes also higher and more distant from the Earth, than the Sun: but the matter is to be understood from the systems themselves, of Copernicus as well as of Tycho, which are to be set out in the following book; since here we are reporting only the common, Ptolemaic opinion.

CAPVT XIV.

Chapter 14.

Quæ item eorundem, & Fixarum ſit (ſed habitis ſimul apparentibus diametris) vera Magnitudo.

What, likewise, is the true magnitude of these same bodies, and of the fixed stars (but with their apparent diameters taken into account as well).

From the assumed distance and the observed apparent diameter of a visible thing, one may judge of its true diameter, its surface, and its thickness or bodily bulk. Therefore, where those same astronomers noted, besides the distance, how great the apparent or visible diameter of each star was, they also pronounced what the true magnitude of each star was.

However, this business too — determining what apparent diameter is to be assigned to each star — seems far more difficult than it is usually reckoned. For the Sun, by its splendour, makes the greatest difficulty of all, whether it is looked at directly or its diameter is explored by some other contrivance. The discs of the other stars, on the other hand, appear now larger, now smaller (even at the same distance from the Earth, and at that altitude above the horizon which is free of refraction), according as the eye views them from different degrees of light and darkness. For they seem the larger, the denser the darkness is; and not even the light in which they appear thinnest diminishes them as much as it should — as, at least, we have found.

Indeed — not to repeat what, concerning the things observed by us, namely the apparent diameters of the Sun and Moon, has already been said earlier; and not to add anything here about the others either — I note only this. The diameter of Mercury, which otherwise appears, and is usually held, to be of two or three minutes, was observed by us to be no greater than a third of a minute. That was when, in this City, in the year 1631, on November 7 in the morning, Mercury appeared on the very disc of the Sun and painted itself on paper by its own little shadow, on this side of the telescope, and its diameter could be compared with the diameter of the Sun without harm. I pass over, moreover, the fact that it left the western edge of the Sun (for it was retrograde) at $10^{h}\ 28^{m}$, having attained a northern latitude of 6′ 20″.

But since, as we have already pointed out, we are reporting [referrimus] [recte: referimus] here the opinion of Ptolemy and his followers, here first of all is how large the apparent diameters were that they had — and that chiefly at their mean distance from the Earth.

Apparent diameter [Diameter apparens] of	is, in minutes [eſt minu- torum]
the Moon	33 [?]
Mercury	2
Venus	3
the Sun	31 [?]

Apparent diameter [Diameter apparens] of	is, in minutes [eſt minu- torum]
Mars	1½
Jupiter	2½
Saturn	1 [?]

About the fixed stars, however, they determined nothing, except that al-Battānī assigned to stars of the first magnitude a diameter of one and a half minutes (that is, as large a one as to Mars too).

Then, from the distance of each star as obtained, and visible diameter, they obtained the true diameter. Then, comparing it with the diameter of the Earth and multiplying cubically, they deduced the thickness or body of each star in such a way as to specify by how much it was exceeded by the body of the Earth, or exceeded that body. Their specification, so far as it concerns the planets, was as follows.

They are	Relation to the Earth	Number of times
the Moon	smaller than the Earth	39
Mercury	smaller than the Earth	19000
Venus	smaller than the Earth	28
the Sun	greater than the Earth	167
Mars	greater than the Earth	1½
Jupiter	greater than the Earth	81
Saturn	greater than the Earth	79

As for the fixed stars, it was as follows, by a certain arbitrary assumption.

Fixed stars of magnitude	are greater than the Earth, by this number of times
first	108
second	90
third	72
fourth	54
fifth	36
sixth	18

This, indeed, is chiefly according to al-Farghānī. For otherwise al-Battānī, who holds stars of the first magnitude to be 102 times greater than the Earth, and stars of the sixth magnitude sixteen times, teaches that among the bodies of the universe, considered according to size, the Sun stands in first place; second, the fixed stars of the first magnitude; third, Jupiter; fourth, Saturn; fifth, the fixed stars that re- main; sixth, Mars; seventh, the Earth; eighth, Venus; ninth, the Moon; tenth, Mercury.

CAPVT XV.

Chapter 15.

Qui Planetarum Adſpectus ſint.

What the aspects of the planets are.

The aspects [Adſpectus] of the planets, which the Greeks call [Greek: Σχηματι[?]μο[?]ς (schēmati[?]mo[?]s, "configurations")] and the Latins configurations, are nothing other than the mutual relations by which the planets regard one another, in so far as they are placed in various parts of the zodiac.

And the number twelve, by which the signs of the zodiac are distinguished, has aliquot parts: a half, 6; a third, 4; a quarter, 3; a sixth, 2. For that reason, if one planet is placed in a certain part of the zodiac and another is distant from it by a half, and is therefore directly opposite it, the aspect between them is said to be opposite [Oppoſitus], or diametral; if by a third, trine [Trinus]; if by a quarter, square [Quadratus]; if by a sixth, sextile [Sextilis].

It did indeed seem, besides, that an aspect should be assigned which would be called uncial [Vncialis], in so far as unity, 1, is also an aliquot part of twelve, and one planet can also be distant from another by one twelfth part of the zodiac. But such an aspect is not usually admitted, and in its place another is admitted, which is assigned, as it were, to the cipher 0: namely, when one planet is at no distance at all from another, but is, as it were, joined to it; hence it is also called the aspect of conjunction [Conjunctionis].

The matter is to be understood from this figure, in which, one planet having been placed, for example, at the beginning of ♈, it is clear that if another is placed at the beginning of ♎, the aspect is one of opposition; if at the beginning of ♌ or ♐, trine; if at the beginning of ♋ or ♑, square; if at the beginning of ♊ or ♒, sextile. Finally, if it is at the beginning of ♈, the aspect is one of conjunction. Both the inscribed lines show this, and so do the characters with which the individual aspects are usually drawn, namely o—o, △, □, ✶, o—.

Diagram. A circle with an outer band divided into twelve compartments, each holding a sign of the zodiac. ♈ stands at the top, left of the vertical diameter, and the signs run anticlockwise from it down the left side — ♉, ♊, ♋, ♌ — to ♍ at the foot, left of the diameter; ♎ stands at the foot, right of the diameter, and ♏, ♐, ♑, ♒ rise up the right side to ♓ at the top, right of the diameter. From the point where the vertical diameter meets the inner circle at the top, straight lines run down to points on the inner circle on each side, and down the diameter itself; further chords join those points, among them a horizontal chord across the lower half. The aspect characters stand on the lines: six six-rayed stars (one on each upper slanting line, one at each side near ♊/♋ and ♑, and one low on each side near ♌ and ♏); four open squares (two on the upper slanting lines, two on the horizontal chord either side of the diameter); three open triangles (one on each long slanting line, one on the horizontal chord at the diameter); a small circle with a stem beneath it on the diameter near the top; and two small circles, one above the other, joined by a

short stroke on the diameter below the horizontal chord. No letters are printed in the figure.

- Signs in the band (anticlockwise from the top): ♈, ♉, ♊, ♋, ♌, ♍, ♎, ♏, ♐, ♑, ♒, ♓
- Aspect characters on the lines: six-rayed star (×6), open square (×4), open triangle (×3), circle with stem (×1), two joined circles (×1)

Moreover, although only the aspect of conjunction deserves to be called a syzygy [*Syzygia*], the word is nevertheless usually applied also to opposition and to the other aspects, by a certain misuse that extends its meaning [abuſu quodam ampliationis].

I pass over, moreover, the fact that an aspect is usually called partile [Partilem] when one planet is distant from another exactly by an aliquot part, but platic [Platicum] when some minutes, or even degrees, are lacking. And since a partile conjunction, specifically, is one in which the planets are in the same longitude, that conjunction is called central [Centralem] and corporeal [Corpoream] in which they are also in the same latitude, and the lower planet places its centre beneath the centre of the upper one and covers the upper one's body with its own. Accordingly, the same is to be said, in proportion, of any planet, taken as the lower body, with respect to the fixed stars to which it applies.

I likewise pass over the fact that these aspects have become especially celebrated among the astrologers, who attribute to them the greatest power both in stirring up the various changes of the air and in governing the fortunes of men. They teach, among other things, that the opposition and square aspects are maleficent, the trine and sextile beneficent, and the conjunction indifferent.

I pass over, again, that if only those five aspects are admitted, it is established that Venus and Mercury cannot be referred to the Sun by any aspect other than that of conjunction, since the former indeed scarcely ever recedes from it by more than a sign and a half, and the latter not even by a whole sign.

I pass over, besides, that Kepler [Kepplerum] has recently introduced many more kinds of aspect — namely the semisextile [Semi-ſextum], or duodecile [Duodecilem], the decile, the octile, the quintile, etc. — inasmuch as he noticed that, with only those five admitted, no account could be given of all the changes observed in the air.

Finally, I pass over the conjunctions they specifically call great [Magnas] and greatest [Maximas]. For just as the conjunction of the four lower planets together is sometimes called great, so the conjunction of Saturn and Jupiter, which occurs every twentieth year, is more often called great; whereas the one that is properly great, or rather greatest, is that of the three superior planets, and it occurs only every eight-hundredth year, as it occurred in the fourth year of this century.

CAPVT XVI.

Chapter 16.

De varijs Lunæ Phaſibus, pro varietate Adſpectuum, Configurationum-ve ipſius cum Sole.

On the various phases of the Moon, according to the variety of its aspects, or configurations, with the Sun.

Since the Moon is a spherical and opaque body, borrows that primary, or silvery, light from the Sun, and is always illuminated by the Sun over half of itself (or even somewhat more, since it is the smaller body), it must follow that, as it continually changes its situation around us — both on other accounts and by its intervening with respect to the Sun itself — it must follow, I say, that it turns towards us now more, now less of its illuminated half. And so what appears of that half is displayed in various forms and figures, which they call phases [Phaſeis].

The phases, however, are usually reckoned and named as four, corresponding to the fourfold kind of aspect listed at the beginning. For just as the conjunction itself is, on other grounds, less properly an aspect, so at that time there is properly no phase at all, since the illuminated part is then wholly turned away from us and turned towards the Sun itself.

I do not mention, moreover, that the Moon, while it is invisible, is called thirsty and silent; and that, while that whole time is called the interlunium [Interlunium], the day of conjunction itself is specifically called [Greek: Νουμηνίαν (noumēnian, "new moon")], new moon [*Nouilunium*]; and likewise [Greek: Εν[?][?], καὶ νέαν (en[?][?], kai nean, "…, and new")], because on that day the Moon is old and new.

The first phase, then, is said to be when the Moon, fresh from conjunction and emerging in the evening from the Sun's rays, turns towards us a small portion of that illuminated part — a portion, indeed, as it were hollowed out (the remainder, which is above, facing the sky). It is then called, and most of all at about the sextile aspect itself, horned [Cornicula-ta] and sickle-shaped [Falcatáque], and in Greek [Greek: Μηνοειδὴς (mēnoeidēs, "crescent-shaped")], namely on account of its own form; other things that imitate that form are called lunulate [*Lunulata*].

The second is when the Moon, already about the seventh or eighth day, when it is a quadrant away from the Sun, and that hollowness has now vanished, turns towards us a full half of the illuminated part. For that reason it is called [Greek: Δικότομος (dikotomos, "cut in two")] [recte: Διχότομος], or bisected [*Bifecta*], because of the hemisphere turned towards us half is still dark; and just as the hemisphere appears to us, because of the distance, as a disc, so that common section [ſectio] of light and shadow appears as a straight line bisecting this disc.

The third is when, the Moon then hastening towards opposition, and especially at about the trine aspect, it shows more than half of the illuminated part; and so it is called [Greek: [?]μφίκυρτος (amphikyrtos, "convex on both sides")],

gibbous on both sides [*vtrimque gibboſa*], because it no longer appears hollow on one side, or cut straight, but swollen on both.

Finally, the fourth is when, having advanced to opposi- tion, the Moon turns towards us its whole illuminated part, since we stand between the Sun and the Moon itself and are therefore seen by it in the same region as the Sun. Shining, then, with an entire disc (or full orb), it is called full [plena], and in Greek [Greek: Πανσέληνος (panselēnos, "all-moon")], as if "all-moon" [*Toti-lunis*].

It is known, further, that the same phases that are attributed to the waxing Moon belong also to the waning Moon (but in reverse order): thus it appears again at about the trine aspect as [Greek: Αμφίκυρτος (amphikyrtos, "convex on both sides")], at about the quadrature as [Greek: Δικότομος (dikotomos, "cut in two")] [recte: Διχότομος], and at about the sextile as [Greek: Μηνοειδὴς (mēnoeidēs, "crescent-shaped")].

It is known also that the part of the Moon where the shadow lies is always turned away from the Sun; and specifically, that the horns themselves point to the west in the old Moon, while in the new Moon they point to the east.

This variety of phases can be represented by the following figure, as if the Moon, running through its orbit from conjunction, appeared successively just as it is shown here by the parts of the circle left white.

Diagram. The phases of the Moon round its orbit. A large circle carries eight small discs set at equal intervals on its circumference. The disc at the top is wholly hatched. The discs at upper left and upper right are hatched except for a narrow unhatched crescent on the side towards the bottom of the figure (lower right on the upper-left disc, lower left on the upper-right disc). The discs at left and right are hatched on their outer half and unhatched on their inner half. The discs at lower left and lower right are unhatched except for a hatched crescent on their outer, lower side. The disc at the bottom is wholly unhatched. Nothing is drawn at the centre of the large circle. The unhatched parts are the "parts of the circle left white" of the preceding text.

- No letters, figures or other labels are printed in the figure.

It is the custom, however, for the same variety to be represented by the figure immediately following, so that it can be understood to some extent how, as the Moon goes round the Earth, the Sun continually illuminates half of it, but of that half now more, now less, now nothing is turned towards us. The semicircles turned towards the Earth, or towards the eye, must nevertheless be conceived as hemispheres, as it were; and the curvature, which cannot be represented on a plane, must be supplied by the imagination.

Diagram. The Moon's illuminated half and the part of it turned towards the eye, in perspective. At the top the Sun is drawn as a face within a ring of wavy and straight rays, on a hatched disc. Below it a large ellipse — a circle seen obliquely — carries eight small discs on its circumference: top, upper left, upper right, left, right, lower left, lower right and bottom. Each small disc is divided by a straight line, with the part below the line hatched and the part above it unhatched; on the upper-left and upper-right discs the dividing line

slopes. At the centre of the ellipse is a small almond-shaped figure with a central ring, like an eye. Pairs of straight lines run from the two sides of the Sun's disc to the two sides of each small disc, and further pairs run from the central figure to the two sides of each small disc.

• No letters, figures or other labels are printed in the figure.

I note a few points here. First, when it is asked why — since all the phases of the Moon show that the Moon always turns the same spots towards the Earth — they nevertheless allow it to be revolved about the centre of the epicycle, in which case the part of that globe which became the front at apogee would have to become the back at perigee: the answer is that this happens because the body of the Moon itself revolves about its own centre in such a way that it is turned back by its own motion just as much as it is turned away by the motion of the epicycle.

Second, that the Moon first appears after conjunction as a very thin sickle, sometimes on the first day, sometimes on the second, and sometimes even only on the third (and the same must be said, in proportion, of its concealment before conjunction). This is because, according as it is swifter or slower, and partly on account of the situation of the zodiac, partly on account of its own latitude, it sets after the Sun now more directly, now more obliquely; and it is freed from the brightness of twilight sometimes sooner, sometimes later, in such a way that it can become visible before its own setting.

Last, that faint light [Luculam] which, in the new and the old Moon, is present besides the silvery horns and makes the rest of the disc visible — which is called secondary [Secundaria] and is commonly reckoned the Moon's own native light — is to be credited as received from the Earth itself: inasmuch as, while the Earth reflects towards the Sun and the region around it the rays it receives from the Sun, the Moon is found within that region and shares in it. For among other proofs is the fact that this light vanishes from the quadrature onwards; as the Moon

goes too far away, or is still too far off, outside the region of that reflection.

It would seem that something ought to be said about the phases of Venus; but they are more conveniently treated in the following book.

CAPVT XVII.

Chapter 17.

De Eclipſi Lunæ.

On the eclipse of the Moon.

What is called in Greek [Greek: [?]Εκλειψις (ekleipsis, "eclipse", literally "a failing")], and in Latin failure [Defectus] or failing [Deliquium], is moreover called labour [Labor], or labours [Labores], especially in the case of the Moon.

Now, the eclipse of the Moon is nothing other than the deprivation of the Sun's light in the Moon because of the interposition of the Earth. That is, since

the Earth is an opaque body, the Moon cannot have it intercepted between itself and the Sun without being stripped of the Sun's light, by which it shines, and being darkened.

I take for granted, however, a familiar fact: that an opaque and spherical body casts a shadow towards the part turned away from the luminous body; and that this shadow is equal, or cylindrical, if the opaque body itself is equal to the luminous one; decreasing, or conoidal, if it is smaller; increasing, or calathoid [Calathoidem], if it is larger (not to mention, meanwhile, that half of the opaque body is illuminated in the first case, somewhat more in the second, and somewhat less in the third) — as even the mere inspection of the following diagram makes plain.

Diagram. The three kinds of shadow cast by an opaque sphere, drawn as three separate figures one above another. Top: a globe with land masses, white on its left half and hatched on its right; two parallel horizontal lines tangent to it above and below run from well to its left (each ending there in a small blob) out to the right edge, and to the right of the globe the band between them is hatched with horizontal lines and keeps a constant width — the equal, or cylindrical, shadow. No luminous body is drawn at the left of this figure. Middle: a small Sun-disc with rays and a face at the left; two straight lines run from it, diverging, tangent to a larger globe with land masses at the right, which is white on its left part and hatched on its right; beyond the globe the hatched shadow widens to the right edge — the increasing shadow. Bottom: a large Sun-disc with rays and a face at the left; two straight lines run from its top and bottom and converge to a point at the right; a small globe, white on its left part and hatched on its right, stands between the lines near the right, and beyond it the hatched shadow narrows to the point — the decreasing, or conoidal, shadow.

- No letters, figures or other labels are distinguished as printed labels in the figure; small marks inside the globes belong to the land masses and the faces of the Suns.

Clearly, then, it is understood from this that, since the Earth is smaller than the Sun and continually casts a conoidal, or top-shaped [turbinatam], shadow towards the part turned away from the Sun, the Moon is indeed free from eclipse if, while it is opposite the Sun, it is outside this shadowy cone; but that it is necessarily eclipsed if it is plunged within it.

It is established, moreover, that the Moon must be opposite the Sun, that is, at the full Moon itself [Plenilunium]; since otherwise the Earth cannot be interposed between it and the Sun.

It is established also that the reason the Moon is not eclipsed at every full Moon is this: although the Earth always casts its shadow onto the ecliptic, the Moon, because of the deflection of its orbit from the ecliptic, is for the most part at such a latitude that it slips past that shadow, now towards the north, now towards the south.

Yet it can scarcely slip past it in every span of roughly six months, because the Sun, as it runs through the ecliptic,

twice a year passes through the nodes, that is, once through the Head and once through the Tail of the Dragon [Caput … Caudam Draconis]; and then, when the Sun is near one node, it can scarcely happen that the Moon is not opposite it, now more, now less close to the other; and so it runs into the shadow more or less, either to the north or to the south of the ecliptic.

I say "scarcely", however, because it happens rarely indeed, but nevertheless sometimes, that the Moon slips past the shadow wholly untouched, even for a whole year — as will happen, specifically, in the fifth year from now.

I say, moreover, "now more, now less", because if the luminaries stand in the nodes themselves, or very near them, then the whole Moon too is plunged into the shadow, and so a total eclipse [Eclipſis Totalis], or eclipse of the whole disc, is produced; and the stay [Mora] within the darkness is longer or shorter according as the centre of the Moon passes through the centre, or axis, of the shadow, or nearer to it, or farther from it — not to mention that the speed or slowness of the motion also plays some part here.

That is, the diameter of the shadow is, or is held to be, nearly three times greater than the diameter of the Moon, and so occupies nearly one and a half degrees where the Moon passes (and this sometimes higher, sometimes lower, according as the Moon is at apogee or at perigee); whereas the Moon itself does not pass through more than half a degree in about one hour.

A total eclipse, moreover — and indeed a central one — can be understood from the figure immediately following, in which A B is the ecliptic; C D the orbit of the Moon; E the Moon first entering the shadow; F the Moon last leaving it; G the Moon at the very centre of the shadow.

A non-central one, on the other hand, can be understood from the figure after it, in which the node is not at the centre of the shadow but outside it — at H, say — and the Moon therefore does not pass through the centre.

Diagram. A central total eclipse of the Moon. A large circle hatched with horizontal lines represents the shadow; concentric with it is a smaller circle hatched with vertical lines. A nearly horizontal line enters the large circle from the left and leaves it on the right; a second, inclined line rises from lower left to upper right and crosses the first at the common centre, where it is drawn dotted inside the inner circle. Two plain circles, the same size as the inner circle, touch the large circle from outside, one at upper right and one at lower left, and the inclined line passes through both.

- E (inside the upper-right plain circle, above the line): the Moon first entering the shadow
- C (upper-right end of the inclined line, beyond that circle): end of the Moon's orbit C D
- B (left end of the nearly horizontal line): end of the ecliptic A B
- A (right end of the nearly horizontal line, below the upper-right plain circle): end of the ecliptic A B

- F (inside the lower-left plain circle, above the line): the Moon last leaving the shadow
- D (lower-left end of the inclined line, beyond that circle): end of the Moon's orbit C D
- G (faint mark in the upper part of the inner, vertically hatched circle, within the hatching): the Moon at the centre of the shadow

Diagram. A non-central total eclipse of the Moon. A large circle hatched with horizontal lines; inside it, in its upper part and not concentric with it, a smaller circle hatched with vertical lines, whose lower edge reaches about the centre of the large circle. A plain circle at lower left and another at upper right each touch the large circle from outside. Two straight lines meet at a point at the left, outside the lower-left plain circle: one rises to the upper right through the lower-left plain circle, the large circle and the vertically hatched circle (dotted within it), and ends beyond the upper-right plain circle; the other runs to the right, nearly horizontal, through the lower part of the lower-left plain circle into the large circle, and a horizontal line continues from the right side of the large circle, at about the height of its centre. A small dot stands inside the lower-left plain circle.

- H (at the left, where the two lines meet): the node, outside the centre of the shadow
- No other letter is printed in this woodcut.

Note, however, that those total eclipses [Eclipſeis Totaleis] which are of the greatest duration (and such are above all the central ones) scarcely exceed four hours, and then by a few minutes, and often stop short of that, because the Moon's motion during that time is not always at its slowest. Note also that almost half of this time is spent in the stay within the total darkness. That is, the time of incidence [Incidentiæ] (from the beginning of the eclipse up to the moment of immersion [Immerſionis], or total obscuration) is only one hour, more or less; and the time of regress [Regreſſus] (from the moment of first emersion [Emerſionis], or recovery of light, up to the very end of the eclipse) is the same.

But if the luminaries are farther from the nodes, then only part of the Moon can pass through the shadow itself, and so only a partial eclipse [Eclipſis Partialis] occurs. This is either greater or smaller according as the distance from the nodes themselves is smaller or greater, and so according as the Moon passes nearer to or farther from the centre of the shadow.

And since the Moon's diameter is understood as divided into twelve ounces [vncias], or equal parts, which they call digits [Digitos], the quantity [Quantitas] of the eclipse is usually expressed in digits (and also in minutes of digits); and it is reckoned greater or smaller according as the obscuration is of more or fewer digits.

A partial eclipse can also be understood from one or the other of the following diagrams. In each of them a double orbit of the Moon is drawn, so that it may be understood why an eclipse occurs now towards the south, now towards the

north; while the first diagram also suggests that the Moon is sometimes eclipsed before it has reached the node, the second,

after it has already passed it. The same points are to be supplied, in the same proportion, for the latter figure of total eclipses.

Diagram. A partial eclipse of the Moon, the first of the two diagrams. A large circle hatched with horizontal lines. A smaller circle stands at its top, overlapping its upper edge: the part inside the large circle is hatched with vertical lines, and the part projecting above it is plain. A second small circle of the same size stands at its bottom, overlapping its lower edge: the part inside the large circle is hatched with vertical lines, and a narrow part projecting below it is plain. Two short horizontal lines stand at the height of the large circle's centre, one to its left and one to its right, each ending at the circle's edge. A straight line rises from the left, outside the large circle, to the upper right, crossing the upper small circle, and ends to the right beyond it. A second straight line runs from the left, outside the large circle, down to the lower right, crossing the lower small circle within its hatched part, and ends to the right beyond the large circle. A brown stain lies on the lower small circle.

• No letters, figures or other labels are printed in this woodcut.

Diagram. A partial eclipse of the Moon, the second of the two diagrams. A large circle hatched with horizontal lines. A smaller circle stands in its upper part, hatched with vertical lines, its top projecting a little above the large circle's edge as a plain arc. A straight line runs from the upper left, outside the large circle, down to the right through the upper small circle; from the right edge of the small circle to the edge of the large circle it is drawn dotted, and it continues as a solid line beyond the large circle to the right. Two short horizontal lines stand at the height of the large circle's centre, one to its left and one to its right, each ending at the circle's edge. A second small circle stands below the large circle, overlapping its lower edge: the small overlapping cap is hatched with vertical lines, and the rest of it is plain. A straight line rises from the lower left, below the large circle, to the upper right, crossing this lower small circle, and ends to the right.

• No letters, figures or other labels are printed in this woodcut.

I pass over here the point that the faint glow [Luculam] which is observed in the Moon while it is eclipsed (and which, especially during a total eclipse, turns the ruddier and the darker, the more the Moon approaches the axis, or centre, of the shadow) seems to come from the refraction of the Sun's rays. Passing by the Earth's atmosphere, these rays are bent towards the axis of the shadow in such a way as to make the shadow itself, as it were, more dilute — the more so, the less one moves away from its edge, and the less so, the more one approaches the axis, where few rays, or none, now arrive; by these the Moon becomes barely visible, and sometimes not even barely.

I also pass over the point that the penumbra [Penumbram], or obscuration, which is almost imperceptible [?] at first and gradually thickens towards the edge of the Moon (and does so, moreover, before the encroachment on the

disc [diſci temeratio] appears, sickle-shaped as it were), arises from this: as the Earth gradually passes in front of the Sun, the light in the Moon is gradually diminished, and that edge of the Moon from which more and more parts of the Sun are snatched away becomes gradually, or more and more, darker. The same is to be said, in proportion, of the penumbra which, towards the end of the eclipse, remains once the limb has already been restored; it fades gradually for this reason, that more and more parts of the Sun are uncovered as the Earth is little by little withdrawn.

CAPVT XVIII.

Chapter 18.

De Eclipſi Solis.

On the eclipse of the Sun.

What is called an eclipse of the Sun would more aptly be called an eclipse of the Earth, since it is the Earth that is then deprived of the Sun's light by the interposition of the Moon, just as the Moon, when eclipsed, is deprived of it by the interposition of the Earth; for otherwise the Sun keeps its light undiminished. Let the Sun nevertheless be said to suffer an eclipse, insofar as it fails with respect to us.

Moreover, that the Sun fails for us because of the interposition of the Moon is clear even from the fact that it fails only at new moons [Nouilunia], that is, when [?] is in conjunction [?].

That it does not fail at every new moon, however, is due to the Moon's latitude. Because of it the Moon passes either above, to the north, or below, to the south, and does not pass directly between us and the Sun itself. It does pass so only when it is at the same node as the Sun (or very near it); and so an eclipse of the Sun occurs only when both luminaries are together either in the Head or in the Tail of the Dragon (or at any rate very nearly so), as can be understood from this figure.

Diagram. An unlabelled woodcut standing above the text. Two large circles of nearly equal size, each drawn as a single line, overlap almost entirely: at the top the outer one stands a little above the other, and at the foot it stands well below it, so that a crescent-shaped band opens between them at the bottom. Left of the figure's centre is a small disc shaded with irregular mottled marks; from it a hatched cone runs to the right and ends in a small oval drawn in outline, the hatching filling cone and oval. Two straight lines run rightwards from the top and the bottom of the mottled disc, diverging, and meet the top and the bottom of a plain circle drawn in outline, larger than the mottled disc, which stands on the right where the two large circles cross. A short stroke stands just right of this plain circle, at the height of its centre. Two small dots inside the large circles below the mottled disc, one above the other, cannot be

told apart from specks of dirt. A small mark stands far to the left of the figure, at the height of the large circles' left edge, well apart from it; it is not resolved.

- No letters, figures or other labels are printed in the woodcut.

It may perhaps seem surprising why far more eclipses of the Moon than of the Sun are seen. But the reason is that the globe of the Moon, by which the Sun is snatched from us, is far smaller than the globe of the Earth, by which the Sun is snatched away from the Moon itself; so the Moon runs into the shadow of the Earth far more easily than our sight runs into the shadow of the Moon.

This, however, is to be understood of a determinate place on the Earth, such as this one in which we live. For if the whole disc of the Earth is considered instead (or half of its surface, taken as if it were a plane), eclipses of the Sun are in no way less frequent than lunar ones; for every six months, for the most part [?], some occur either here or there on the Earth.

This happens because the Moon, being, as was said just now, far smaller than the Earth, cannot snatch the Sun from the whole disc of the Earth turned towards the Sun, but can only cast its shadow onto some part of it, now onto this part, now onto that; and so

it also usually happens that in one place on the Earth the eclipse is then total, while elsewhere it is only partial, and elsewhere again there is none at all.

The matter will be easy to grasp from this common diagram. In it, where the Sun is at A, the Moon at B and the Earth at C, it is evident that the Sun is snatched away whole, by the interposed Moon, from someone living at the point D of the Earth; half of it from someone living at E; nothing of it from someone living at F; and likewise more or less of it from those living in the other places.

Diagram. A woodcut standing to the right of the text. At the top is a Sun drawn with a face and long and short rays. Straight lines descend from the left and right edges of the Sun towards the foot of the figure: two of them cross each other at about mid-height, at the left side of a small circle, and the outer two run down to the left and right sides of a circle at the foot. The small circle at mid-height has its upper half drawn in outline; from its middle a band hatched with vertical lines runs straight down to the circle at the foot and covers the right-hand part of it. The circle at the foot is shaded on its left-hand part with irregular mottled marks, with small round marks along its left edge.

- A (above the Sun)
- B (right of the small circle at mid-height, at the height of its middle)
- E (above the circle at the foot, inside the lines, a little left of the hatched band)
- F (left of the circle at the foot)
- D (right of the circle at the foot)
- C (below the circle at the foot)

In passing, moreover, it may be noted from this diagram that so great a parallax [diuerſitatem adſpectuum] arises from the Moon's nearness that astronomers are rightly concerned about its parallax: not only the one that is

called the parallax of altitude, but also the one that is called the parallax both of longitude and of latitude, so that they may determine where, and how great, an eclipse of the Sun it is going to produce.

When an eclipse is partial, it is usually represented in this form, and is also marked out by twelve parts of the diameter, or digits [Digitos], and their minutes.

Diagram. A woodcut standing to the right of the last lines of text, below the first. A disc hatched with horizontal lines and crossed by irregular wavy lines overlaps a second disc of about the same size standing a little lower; of the second disc only a crescent along its lower edge is exposed, hatched dark, with the bases of rays shown in it as light triangles.

• No letters, figures or other labels are printed in the woodcut.

Meanwhile it is no wonder that the whole Sun can fail because of the Moon. For although the Moon is smaller, it is nevertheless also nearer to us, so that its apparent disc can be made equal to the apparent disc of the Sun, and can thus cover the Sun entirely.

There is, however, this difference between a total eclipse of the Sun and a total one of the Moon. The total eclipse of the Moon usually takes place with a notable stay [Mora], as though the Moon were unable to free itself quickly from the Earth's shadow; the total eclipse of the Sun, by contrast, cannot take place with a stay, at least not with a very sensible one (and so the darkness that is sometimes produced, very dense even around midday, so that stars are seen and birds hide or fall down, etc., cannot last very long). The reason is that the Moon, running beneath the Sun by its own motion towards the east, as soon as it has touched the eastern limb of the Sun with its own eastern limb, and has thus covered the whole Sun, begins to leave the Sun's western limb with its own western one, and so to uncover the Sun.

Moreover, it sometimes happens, because the apparent disc of the Moon at apogee [Lunæ Apogeiæ] is smaller than at perigee, and therefore smaller than the disc of the Sun itself; it happens, I say, that while the Moon at apogee runs beneath the Sun and has its centre joined to the Sun's centre, a whole limb of the Sun is left over all round, like a golden bracelet or a kind of golden circle, since the Moon, of course, does not cover the whole.

But if you ask what the greatest duration of an eclipse of the Sun is, it seems clear that it is of about two hours, more or less. For since the Moon completes in each hour about half of one degree, more or less, which is the size of the Sun's diameter that has to be run across, it is therefore necessary

that, from the moment the Moon has touched the western limb of the Sun with its own eastern limb and has made the beginning of the eclipse, it spends an hour until that same limb reaches the eastern limb of the Sun and produces the middle of the eclipse. And since only then does the Moon's western limb reach the western limb of the Sun, which it also soon leaves, so that as the incidence [Incidentia] ceases the emersion [Emerſio] begins, it must again

spend an hour until that same limb reaches the eastern limb of the Sun and, passing beyond it, makes the end of the eclipse.

INSTITVTIONIS ASTRONOMICÆ LIBER TERTIVS, SIVE SPECIALIA COPERNICI, ET TYCHONIS SYSTEMATA.

Book Three of the Astronomical Instruction, or the Particular Systems of Copernicus and of Tycho.

CAPVT I.

Chapter 1.

Quos imitatus Copernicus in Syſtemate

Whom Copernicus imitated in devising

confingendo fuerit.

the System.

Since we must now speak, by way of an appendix, about the world-system [Mundano Syſtemate] according to the mind of Copernicus, and then say something about the one, not very unlike it, that Brahe substituted for it, it must be said at the outset that whatever we say, especially about the former, aims only at this: that, since it has become celebrated, it should be explained what kind of system it is and how it is defended by its proponents. For we do not otherwise present ourselves as its guarantors and sureties.

To begin with, since the system, or hypothesis, of Co-

pernicus supposes that the Earth moves, it should therefore be known that the opinion which attributes motion to the Earth is very ancient: it is shown, in fact, to have been the opinion even of Pythagoras and the Pythagoreans, although not all of them expounded and defended it in one way.

For some held that the Earth, standing at the centre of the world, is turned round eastward about its own axis in the space of 24 hours, and that from this it comes about that the Sun and the other stars appear to be turned round westward in the same space of time.

So held Ecphantus the Pythagorean, and Heraclides Ponticus, and Plato while he was young; and some others besides.

It should be noted, however, that these men did not on that account take all motion away from the stars, but took away only the daily motion, as something imputed to them from the motion of the Earth; and they left to each star its own motions, such as the monthly motion to the Moon, the annual to the Sun, the two-yearly to Mars, and so on. For they could not explain in any other way the conjunctions, the oppositions and the other aspects of the planets.

It follows that one may well wonder that Nicetas, in Cicero, held that the heaven, the Sun, the Moon, the stars, in short all things above, stand still, and that nothing except the Earth moves.

Others held, first of all, that two things stand unmoved: on the one hand the sphere of the fixed stars, which they regarded as the walls of the world; on the other the Sun, which, dwelling at the centre, they called the guard of Jupiter [Iouis cuſtodiam] and the household gods [Lareis], or hearth [Focum], of the universe. Next, between the fixed stars and the

Sun, they made the planets movable, and among them the Earth, which they also maintained moves not only with a daily motion about its own axis but also with an annual motion about the Sun itself.

So held Philolaus, Aristarchus of Samos, Plato when already more mature, and likewise Seleucus the mathematician, and Hicetas, or Oicetas (for the same man seems to be meant under either name, and indeed perhaps also under the name of Nicetas, so that his opinion may not have been fully grasped by Cicero himself), and several others besides.

Now Nicolaus Copernicus, who was a canon of Toruń [Torunenſis] and flourished a little more than a hundred years ago, imitated these latter; but in such a way, nonetheless, that he supplied some things which the authors do not report as having been noticed by the ancients.

Since the opinion was revived by him (for it had not been possible to restore it in the same way through Cardinal Nicholas of Cusa, a champion of the Earth's motion, a century earlier), it has been embraced by Rheticus, Rothmann [Christoph Rothmann], Mästlin [Michael Mästlin], Lansbergen [Laudſbergius] [recte: Landſbergius] [Philips van Lansbergen], Schickard [Wilhelm Schickard], Kepler, Galileo and almost countless others.

And that is not to mention Origanus, Longomontanus and some others among the more recent writers, who, adhering to the former and keeping the Earth at the centre, attributed the daily motion to it; and who both left to the planets their own motions, set out more explicitly than the ancients had, and granted to the firmament, or sphere of the fixed stars, that slow motion, that is, one revolution within 25,000 years, which was discussed in the preceding book.

It should be noted here that by the name "Earth" [Terræ] or "Tellus" [Telluriſve] is meant this globe compacted of earth specifically so called, of the water spread through it, and of the bodies born from these. Such bodies are to be reckoned as animals, plants, stones, minerals, meteors [Meteora], and fire itself (inasmuch as it is produced from fatty matter, which is earthy); also the air, or atmosphere (inasmuch as it is nothing other than a certain texture of vapours, or of corpuscles exhaled from earth and water and from mixed things), which is raised to no very great height and meanwhile clothes all round the more solid orb of earth and water, almost in the way that down clothes a quince.

CAPVT II.

Chapter 2.

Quo proinde ſitu, atque ordine Terram, Sideráque

In what position, then, and in what order the Earth and the stars

habuerit.

were placed by him.

It must further be understood, from the diagram set here below, what the arrangement of the Earth and of the stars is, partly according to those ancients, partly according to Copernicus and the more recent writers.

That is, the region of the fixed stars is taken as the outermost part of the world, as entirely unmoved, and, as far at least as appears to sense, as orbicular or spherical; although its figure cannot be determined by us with certainty, since we neither see its outermost surface nor discover into what, where or how it ends; nor can we in any way discern even its innermost surface, since whatever is above, all the way from the region of the upper air,

Diagram. A woodcut of the world-system, centred in the upper two-thirds of the page. At the centre is the Sun, drawn with a face and rays and carrying no letter. Around it run six concentric circles, and outside these a larger circle set all round with six-pointed stars. No lettered points (A, B, C …) appear on the block; the labels are signs only.

- ☿: on the first circle from the Sun.
- ♀: on the second circle.
- [?]: on the third circle, at the centre of a small circle; the sign is shaped like the numeral 4 with a cross stroke on its bar, and is not resolved to any sign.
- ☾: a crescent on the right rim of that small circle.
- ♂: on the fourth circle; drawn as a small circle with an arrow pointing right.
- ♃: on the fifth circle, at the centre of a set of small concentric rings, with small stars set on and about the rings.
- ♄: just above the sixth circle, at the top.

we hold, as it were, to be set at the same distance, or on the same surface; whereas the fixed stars may be placed both nearer and farther, and the inequality that appears among them may be due as much to their smaller and greater distance as to the greater and smaller bulk of their bodies.

The Sun, for its part, is taken as the centre of this visible

vault [concamerationis], or rather it occupies its centre, being itself likewise unmoved. Yet although the Sun is unmoved, inasmuch as it does not leave its place, it is nevertheless shown to turn in that very place — that is, about its own

axis — within 27 days. This is inferred from the very motion of the spots that have been observed on it since the telescope was invented.

With these two, as it were, immovable bounds established, the planets themselves are arranged as movable bodies in the interval between, inasmuch as they perform various motions around the Sun and beneath the region of the fixed stars.

First, then, next to the Sun is placed Mercury, as the planet that describes the shortest circuit of all around it and completes that circuit most quickly — namely, within very nearly three months.

In second place is set Venus, which, as it exceeds Mercury in compass, so exceeds the planets that follow in speed, completing, namely, its circuit within seven and a half months.

Third comes the Earth itself, which, as it encloses Venus within its circuit, so completes that circuit more slowly — only, that is, within twelve months, or one year.

Fourth, Mars, which both is carried round the Earth and does not complete its circuit except in very nearly two years.

Fifth, Jupiter, which both goes round Mars in like manner and does not complete its circuit except in very nearly twelve years.

Sixth, Saturn, whose circuit encloses all the others and is completed only within very nearly thirty years.

Copernicus adds that the Earth, placed between Venus and Mars, passes between them at such a distance from each that in their very interval it has the Moon carried round it as an attendant [aſſeclam]. The Moon, together with the Earth, is carried round the Sun with an annual motion, yet in such a way that meanwhile it is carried round the Earth itself with a monthly motion.

It has since been possible to add that Jupiter, proceeding in like manner between Mars and Saturn, is borne at such a distance from them that in their interval it has carried round it, as attendants, four moons as it were — or, if you prefer, little stars visible with the telescope alone, and named by Galileo the Medicean Stars [Medicea Sidera]. These are carried round the Sun together with Jupiter itself with a twelve-year motion, yet in such a way that meanwhile they perform their own particular motions around Jupiter: the innermost in 1¾ days; the next in 3½ days; the third in 7⅙ days; the outermost in 16⅔ days.

We would add that two attendants are also carried round Saturn, if the two little orbs that sometimes appear at its sides were constantly of the same form, and did not at times grow pointed and, with arms as it were stretched out and a gap left in the middle, cling to Saturn like little handles; at times become as it were one and the same body with it, the small intervals on either side towards the outermost points being drawn out and contracted; and, besides, transform the body of Saturn with such variety that one must altogether wait until the whole diversity, both of its appearances and of its periods, has been carefully observed before anything is pronounced.

It will further have to be added that two attendants are carried round Venus, if what is written is true: that two were observed a few months ago by Fontana of Naples [Francesco Fontana]. With that excellent telescope of his he is said to have discovered even in Mars something like a small globe at the centre, and next to the rim a circle, as it were, of a blackish colour; just as he also found in Jupiter two or three blackish transverse little bands. Nothing of the kind have we yet been able to detect with our own telescope, though it is a Galilean one, and an excellent one at that.

However that may be, it can be established that some planets are primary, and as it were principal — such as Mercury, Venus, the Earth, Mars, Jupiter and Saturn — and some secondary, and as it were their footmen [pediſſequos]: namely the moons, both the Earth's and Jupiter's, and any others that may be carried round the remaining globes.

Lastly, Copernicus held that the space enclosed between Saturn and the fixed stars, all the way to them, is huge, and almost immeasurable. For he also made the distance of the fixed stars from the Earth so great that not only is the globe of the Earth itself, compared with the region of the fixed stars, like a point — which no one fails to admit — but even the orb which he himself otherwise calls the Great Orb [Magnum orbem] is like a point: that is, the heaven, as it were, of the Earth, or the orb in which the Earth completes its circuit around the Sun, and whose semidiameter, accordingly, is the very distance between the Earth and the Sun.

CAPVT III.

Chapter III.

Cuiuſmodi triplicem motum Telluri attribuerit.

What kind of threefold motion he attributed to the Earth.

The Earth's place being supposed, the motion which Copernicus assigned to it is threefold: the Diurnal, the Annual, and that of Inclination.

The Diurnal is the Earth's very revolution about its own axis; and this it performs by moving toward the east and completing its circuit within 24 hours. So it comes about that the same part of the Earth (for example this one, in which we live) now enjoys day, when it is turned toward the Sun, and now undergoes night, when it is turned away; and meanwhile the parts of the heaven themselves which, in order, as it were come to meet it and are uncovered appear to rise, while those which on the opposite side go away backward and are hidden appear to set.

The Annual is the very progression of the same Earth through the Zodiac, that is, beneath the Signs of the Zodiac: while it advances between Venus and Mars, and presses on also toward the east, it is carried round the Sun itself, and completes its circuit, as has already been said, within a year. Namely, while its surface is rolled about its centre, or its own axis, by the diurnal motion, its

centre meanwhile is carried forward gradually according to the succession of the Signs; in the same way that, when a globe is rolled upon a plane, its centre is moved forward along the length of the plane, while its surface meanwhile revolves about the centre, or axis, of the globe.

He holds, moreover, that it comes about from this motion that, because, when the Earth stands between the Sun and one Sign, the Sun then covers the opposite Sign and is said to be in it; therefore, with the Earth

placed, for example, in Libra, the Sun appears to be in Aries; and as the Sun passes from Libra into Scorpio, the Sun appears to pass from Aries into Taurus, and so on in turn. So it follows that it is the Earth which really runs through the Zodiac and describes the Ecliptic, whereas it is the Sun itself which runs through it and describes it apparently.

Finally, the motion of Inclination, or of Declination, is the very deflection of the Earth's axis from parallelism with the axis of the Ecliptic, together with its holding of itself perpetually in parallelism with itself, in any position whatever; on account of which it also, besides, always remains parallel to the axis of the world, and keeps the Earth's equator parallel to the equator of the world itself. And so this may here be called not so much truly a new motion as, as it were, a certain modification of the motions above. It can be understood, moreover, to come about in the same way, proportionally, as when a boys' top is spun round upon a plane and traces various little circles with its point: the top's axis itself both keeps itself parallel to itself, that is, in an always perpendicular position, and also keeps the base of the top always parallel to the horizon itself.

That is to say: suppose that in the Great Orb, of which mention was made a little earlier, you conceive both the Ecliptic and the Equator intersecting it, whose plane is understood to be produced all the way to the fixed stars; and at the same time suppose that the Axis passing through the Sun is understood to be carried across into the same region, until it ends in the poles. Then imagine the Earth to be at the beginning of Aries, and its equator to coincide with the equator of the world, or with its plane; the Earth's axis will then indeed be parallel to the axis of the world. But it is further only to be conceived,

that, while the Earth proceeds from there toward Taurus and further on, its axis does not spread apart but is always kept parallel both to itself and to the axis of the world; and that from this it comes about that its equator remains parallel to the equator of the world.

You will grasp the matter well enough [Rem non malè capies] if, taking an ordinary Sphere in your hands, you treat it as the Great Orb, and the innermost little globe, accordingly, as the Sun; its axis as a portion of the axis of the world, and its Equator as a circle lying in the plane of the Equator of the world. Then also take in hand some little globe pierced through by its own axis, which you are to regard as the Earth, and apply it to the Sphere at the beginning of Aries in such a way that it lies in the very plane of the equator and has its little axis parallel to the axis of the Sphere itself. After that, carry the little globe in this

manner gradually, and in order, through the Ecliptic, so that both axis is held parallel to axis, and equator to equator, unfailingly.

Further, so far as it is possible to represent the matter in some fashion on a plane, in the following diagram let A B C D be the sphere of the fixed stars; A C the axis of the world; E F G H the Great Orb; and on its surface F H the Equator, and its axis passing through the Sun (understood to lie beneath, at the centre) E G. Let I K be the Ecliptic, and the Earth advancing through it that multiple little orb, marked everywhere with its own axis and its own Equator. One may see that, if the Earth is indeed in the Equator of the Great Orb, it has its Equator coinciding with the Equator of the world; and its axis not indeed coinciding with the axis of the world, but nevertheless parallel to it (namely, it is to be conceived that the axis A C, or its portion E G,

Diagram. A woodcut filling the upper two-thirds of the page. A large outer circle encloses a smaller inner circle at its centre. A solid chord crosses the top of the outer circle from about P to about T, and another crosses its bottom from about Q to about V. Five dotted lines run almost vertically, slightly slanted, from the top points P, R, A, X, T down to the bottom points Q, S, C, Y, V in that order; a sixth dotted line runs diagonally from N at the upper left to O at the lower right, crossing the others near the centre. A dotted, slightly tilted horizontal line runs from B at the left edge of the outer circle to D at its right edge, passing F and H at the sides of the inner circle. Inside the inner circle a solid line rises from lower left to upper right, carrying five small circles, each drawn with a cross of two lines.

- N (on the outer circle's top arc, upper left)
- P, R, A, X (above the outer circle's top arc, left to right)
- T (on the outer circle's top arc, upper right)
- Q, S, C, Y, V (below the outer circle's bottom arc, left to right)
- O (below the outer circle's bottom arc, lower right)
- B (left end of the dotted horizontal line, at the outer circle)
- D (right end of the dotted horizontal line, at the outer circle)
- E (above the top of the inner circle)
- G (below the bottom of the inner circle)
- F (at the left of the inner circle, just above the dotted horizontal line)
- H (at the right of the inner circle, just below the dotted horizontal line)
- I (left of the lowest small circle)
- M (below, between the second and third small circles)
- L (above the third small circle)
- K (right of the highest small circle)

passes through the centre of the Great Orb, whereas the little axis L M is on the surface of that same orb.) But if the Earth is outside the Equator of the Great Orb, one may see that it always keeps its own Equator parallel to the Equator of the world itself, and its axis likewise to the axis; and that it never suffers it to be turned aside toward the axis of the Ecliptic, which is here understood to be N O.

It should be noted in passing, however, that when you hear "Equator of the world", "Axis of the world", "Poles of the world" spoken of here, this is done with the name retained from the common Hypothesis;

insofar as, when the Earth is revolved toward the east, the whole World appears to be revolved toward the west along this Equator, about this Axis, upon these Poles; and these are in reality nothing other than the Equator, the Axis and the Poles of the Earth itself, turned round by its diurnal motion.

Why, further, this Third motion was devised and introduced by Copernicus will be told more conveniently a little later.

CAPVT IV.

Chapter IV.

Quam ob rem de motu, quieteve Telluris, aut Siderum, fiendum ſenſui non duxerit.

Why he did not consider that sense was to be trusted about the motion or rest of the Earth, or of the Stars.

Since, however, it is brought into controversy whether these motions belong to the Earth or not, and the matter seems to have to be decided by sense or by reason, Copernicus therefore laid down that this dispute cannot be settled from what appears to sense.

For indeed, as Aristotle himself also attests, for a thing seen to appear to move it makes no difference at all whether it is the thing itself or the eye that sees it that moves; for in either way the motion is imputed by the eye to the thing seen. And the Philosopher himself [ipſæ] also, to demonstrate the point, uses the example of people sailing, to whom, as they put out from port, the land appears to recede:

We are carried forth from the harbour; and lands, and cities recede.

Therefore, says Copernicus, for the Stars to appear to move toward the west, it makes no difference whether they themselves really move there, or the spectator's eye, together with the Earth, moves toward the east: since in either way those things will ap-

pear to move toward the west. And for the Sun to appear to go away from Cancer into Leo, it makes no difference whether it really goes away, or whether it is the spectator who, together with the Earth, goes away from Capricorn into Aquarius; since in either way the Sun will appear to pass from Cancer into Leo.

Accordingly, the matter seems to have to be conceived thus: as if someone from inland, with no experience of the sea, were carried asleep and unaware onto a ship. For that man, once woken, would swear that the shore is approaching or receding, but that the ship stands motionless, inasmuch as he will see all the parts of the ship remain always in the same position relative to one another, and the sailors throughout it, as throughout a house fixed to the ground, resting, running about, climbing the mast, etc., and the shore itself meanwhile becoming

either nearer to him as he approaches, or more distant as he recedes. So we, born, brought up and accustomed on the Earth itself (which is still more than having been transferred there), will readily swear that it is the Stars that rise or set for us, but that the Earth is motionless; because we observe all of its parts set around us always in the same position relative to one another, and on it, as in a fixed dwelling, we rest and move about in various ways; while on the other hand the Stars, placed outside it, meanwhile come into a higher and a lower position for us.

The only difference is that he can leave the ship and set himself down in the harbour, from where he may detect and infer his illusion; but we may not leave the Earth for a fixed place from which we might experience the Earth being moved and correct the deception of our sight.

Hence, because as long as we are on the Earth, the eye is al-

ways in the same condition, and for that reason incapable of serving to decide the controversy whether the Earth moves or not, therefore Reason alone remains, which may as it were carry a torch before us, and teach which side of the problem is the more probable by far.

Further, both Copernicus and those who stand on his side think that they are the stronger by the vote of reason. This, however, is to be learned both from the reasons by which they defend their opinion, and from the objections which they set against the reasons of those who attack it.

CAPVT V.

Chapter V.

Quæ viſæ magis congruæ rationes ad adſtruendum motum Telluris Diurnum.

What reasons seemed more fitting for establishing the Diurnal motion of the Earth.

For as regards the Diurnal motion indeed: FIRST, they say, there is removed that most vast sphere of the primum mobile, built on above the firmament and devised solely so that all the lower things may be understood to be carried off by it with a diurnal motion. Namely, the Earth, by the simple revolution of its own little body toward the east, performs the office of the primum mobile; and, achieving as much as that Sphere, it meanwhile relieves the heavens and all the stars of that labour, so that they by no means suffer that incessant carrying-off.

And this indeed accords with the genius of Nature, which never accomplishes by roundabout ways what it can by a short cut; nor by more means, whenever something can be done equally conveniently by fewer.

SECONDLY, there is accordingly removed that insane rapidity with which that Sphere must be carried. For as to the rapidity that is also objected against the motion of the Earth, inasmuch as a point taken on its equator rivals the speed of a cannon-ball as it leaves the barrel: with how much more monstrous a swiftness, I ask, must a point taken on the very equator of the primum mobile

be carried, when a point taken on the equator of the firmament also, according to the common opinion, must be carried off fifty thousand times more rapidly than such a point of the Earth?

Not to mention, meanwhile, that Nature, which accomplishes all things harmoniously, does not fit small things for rest and huge things for motion, but rather the former for motion and the latter for rest. And here indeed this holds all the more, in that on the other hand the Earth is apt to roll by the nature of its figure, whereas it is not known, as was said a little before, what figure the outermost body of the World has on its outside; since it is also probable that it has the figure best suited for resting or standing still. For also: that otherwise so great a Machine as the whole World should be incessantly whirled round, and indeed with an unimaginable swiftness, while this little pill of the Earth alone, held as a point, should stand motionless and remain unvaried — how could that be held fitting or harmonious?

THIRDLY, there is removed the perpetual violence done to the lower heavens, while, besides their own inclination by which they move toward the east, there is an external principle which, impressing a force toward the opposite region, draws them away toward the west. And if indeed the violence were

less than the inclination of nature, the thing might seem tolerable. But that the violence should so exceed that inclination that in Saturn it is more than ten thousand seven hundred times greater, and that this so great excess should be multiplied in the firmament more than eight hundred and ninety times — how could the thing seem able to be tolerated?

From this, accordingly, it comes about that one may wonder at the authors of the common opinion. They think it foreign to the nature and perfection of the divine bodies to be carried unequably, and yet they reckon it fitting that those very same bodies should be pulled apart so greatly; and while they seem to revere Nature, they nevertheless do not fear to inflict an unspeakable violence upon her — and this when they have especially professed that nothing which is violent is of long duration.

FOURTHLY, there is removed that absurdity, if not rather impossibility, which those do not sufficiently guard against who will have a lower sphere revolve within a higher one and at the same time be carried off by it. For since both surfaces — namely the convex surface of the former and the concave surface of the latter — must be as perfectly even as they are contiguous, it is assuredly evident that in this case no impression can be made, because of the unvarying position of each in its own place; and so, further, because of the absence of pressure, none of which can be understood to occur without a departure from place or a joining of parts.

Not to add that the celestial spaces are proved to be fluid, and not, indeed, occupied by solid spheres that are carried off: this is shown both from the phases of Venus, of which somewhat later; and from the passage of comets through them; and from the absence of refractions; and by other arguments of that kind.

FIFTHLY, there is removed the contrariety, or pulling apart,
of the motion of the same planet in contrary directions; and there is left only one motion, and in one direction, and that itself indeed quite moderate. For Saturn, for example, will not go round the Earth every single day; rather, with the Earth relieving it of this motion, it will traverse the zodiac only once in thirty whole years. And the Moon will not go round the Earth thirty times in a month; rather, with the Earth taking this motion upon itself, the Moon will go round only once; and so with the other planets.

In the same way, moreover, comets, if any appear on high, will not be carried at once both by their own passages and by the carrying-off of the primum mobile; rather, they will be driven through the aether by their own passages only, while the daily motion is meanwhile ascribed to them from the very revolution of the Earth. And again in the same way, if any New Stars should be born in the heavens which lack special motions — like that celebrated one of the year 1572, seen in the constellation of Cassiopeia, and again another of the year 1604 in the foot of Ophiuchus [Serpentarius], at the time when the Great Conjunction of the three superior planets took place there — in the same way, I say, these stars will stand fixed just as the perpetual fixed stars do; and the Earth, by its own revolution, will ascribe the daily motion to them just as to the perpetual fixed stars.

LASTLY, they say: just as it is more fitting for the sea-coast to be surveyed all round by a ship than the ship itself by the coast; for an orator's face to be turned in order towards the various parts of the auditorium than for the whole auditorium to be turned round about towards the orator's motionless face; and other similar things of that kind — so it seems more fitting for the Earth to turn itself towards the various parts of the heaven than that the
whole celestial region should be carried round the Earth while it stays motionless; and most of all since, as has been said, the same thing appears either way.

Moreover, they add, it is all the more consistent for the Earth to turn its various parts towards the Sun than for the Sun itself to survey round the various parts of the Earth, in that it is the Earth that needs the Sun, not the Sun that needs the Earth; since it is more according to nature that what needs another thing should tend towards it, than that the thing itself, needing nothing, should tend towards that which needs it.

CAPVT VI.

Chapter VI.

Quæ viſæ magis congruæ ad afferendum Annuum.

What seemed more fitting for asserting the Annual motion.

Now as regards the Annual motion: FIRST indeed, they say, since the Sun is as it were the heart, and the source of light, heat and vigour by which the

whole planetary region is suffused and animated, a place most fitting for it is assigned in the middle of all — namely, so that this Ruler and, as it were, Prince may be seated where it is opportune,

To whose measures both the gods may move, and the world Receive its laws, and keep the covenants prescribed.

Certainly that almost monthly revolution of the Sun about its own axis, of which a little before, gives them occasion to conceive that the Sun, by the rays it sends out from itself, compels all the planets to imitate the same motion; and that it comes about from this that the nearer each planet is to the Sun, the more quickly it completes its circuit, as though, because of the more closely packed rays, it were more powerfully

carried round. Nor indeed, they hold, does either the weak force of the rays or the bodily mass of the planets stand in the way of this. For the planets, they hold, are indeed of themselves neither heavy nor light, and so can change place at the least impulse or push; while the rays — which we find by experience to be driven against bodies, to be reflected, to steal in beneath them, and to break up, burn up and dissolve them — can be endowed with such a force of driving as to move the planets, which in no way resist, and lead them round.

SECONDLY, if you consider the arrangement of the planets as regards both size and motion, Mercury will be at once smaller and swifter than Venus, Venus than the Earth, the Earth than Mars, Mars than Jupiter, Jupiter than Saturn; and this series is both harmonious and worthy of nature's design. And the series of motions, indeed, is beyond all dispute; but as regards the series of sizes, there are indeed those who think that the Earth is greater not only than Mars but also than Jupiter. But of course, since the matter depends on fixing the parallax and the apparent diameter — a business that was intimated above to be full of hazard — it is no wonder that it seems otherwise to some than to the rest.

But however that may be, it is at least agreed that in the common system nothing can be more disordered, as regards both the series of sizes and the series of motions. For in it the Moon is greater than Mercury, Mercury smaller than Venus, Venus smaller than the Sun, the Sun greater than Mars, Mars smaller than Jupiter, Jupiter greater than Saturn. And again: the Moon moves with a monthly motion, Mercury with an annual one, Venus also, the Sun likewise, Mars in 2 years, Jupiter in 12, Satur-

n in 30, the firmament in 25,000, the ninth sphere in 1700, the tenth in 3400, the primum mobile in 24 hours.

THIRDLY, from this it is splendidly explained why Mercury and Venus do not digress far from the Sun, and never have the Earth placed between themselves and the Sun, whereas Mars, Jupiter and Saturn digress to the utmost, and sometimes catch the Earth between themselves and the Sun. Namely, even an inspection of the system alone shows the matter clearly. For according to the common opinion one has to imagine a line stretched between the Earth and the Sun, on which the centres of the epicycles of both Mercury and Venus cling as though tied to it; and yet the centres of the epicycles of Mars, Jupiter

and Saturn are free of this tie; nor can any other reason for the disparity be offered than the system's want of harmony.

Not to mention, meanwhile, how enormous the thickness of the heaven of Venus had to be made, so that within it an epicycle of such capacity might be hollowed out as — being meant to take in the greatest digressions on either side of the Sun — would display a diameter subtending a fourth part, and more, of the circuit of the heavens.

FOURTHLY, it is more splendid still that, once this system and the motion of the Earth through the zodiac are supposed, not only is that medley of epicycles abolished, but all the stations and retreats of the planets are removed, and each planet is driven with its own single motion, at a single steady rate, and in the same direction, with the utmost constancy — as indeed befits such great bodies; and meanwhile whatever there is of station and of retrogradation, and also in the very

direct motion, of alteration of motion, is ascribed to the planets themselves by sight, because the Earth is carried among them.

For as regards Mercury and Venus, indeed, they do not by turns move forward in the order of the signs and go back against the order of the signs. Rather, they — who, if they were viewed from the Sun as the centre of their motions, would be seen always to go in the order of the signs and to run through the zodiac at one steady rate — must necessarily appear to us, who are situated outside this centre and outside their circuits, to go and to come back; and while we meanwhile are carried round the same centre, but more slowly, they must appear to complete their goings and returnings now in these places of the zodiac, now in those.

But although the stations are understood in this hypothesis just as in the common one, that they [?] nevertheless do not appear in a descent [excenſu] [recte: deſcenſu] or ascent along an epicycle contained between the Sun and the Earth, but rather along a circle whose centre is the Sun itself (so that these two planets now come below, or on this side of, the Sun, now go off just as far above, or beyond, it — as both the ancient Egyptians and afterwards Martianus Capella and some others held), is both argued by certain other things and proved conclusively by the very phases of Venus observed with the telescope.

Venus, that is, cannot appear full (or nearly so) when she emerges from the Sun in the evening and is heading for her first station, except because, having got beyond the Sun, she turns towards us [?] her own hemisphere illuminated (or as nearly as possible). Nor halved, when she is about the mean longitudes, except because she presents only half of the same. Nor horned when, below, descen-

ding, she returns to the Sun in the evening, except because she presents less than half. Nor again horned when, emerging from the Sun in the morning, she hastens towards the second station, except because then too she presents less than half. Nor again bisected about the mean longitudes, except because she again presents half. Nor, finally, full again when she returns to the Sun

in the morning, except because she again presents her whole hemisphere (or nearly so) illuminated.

Diagram. A woodcut filling the lower part of the page. Two concentric circles surround a Sun drawn with a face and rays at the centre. The sign of Venus stands on the outer circle at its top, and the sign of Mercury on the inner circle at its top. Six small circles are set on the outer circle: at upper left (open, with a thin hatched sliver along its upper-left edge); at upper right (its upper part hatched, above the line of the outer circle); at left (left half hatched); at right (right half hatched); at lower left (largely hatched); and at lower right (its lower-left part hatched, the upper right open). The line of the outer circle is broken in places in its lower half, beside the lower small circles. Below the outer circle is a globe of the Earth with continents, from which dotted lines run in pairs up to the upper-right, right and lower-right small circles. No letters are printed in the figure. (The hatching of the four lower small circles is described at reduced magnification and is unverified.)

- ♀ (on the outer circle, at its top): the sign of Venus
- ☿ (on the inner circle, at its top): the sign of Mercury

All of which can indeed be understood even from inspection alone of the figure set beside this, insofar as the phases that are on the left reproduce the disc of Venus as it is shown to the eye; and those that are on the right suggest that no other can be shown, because of the illuminated half of the globe, which indeed always faces the Sun, but is now more, now less turned towards the eye, or turned away from the eye. I pass over, moreover, the fact that it is known that, if Venus were carried on an epicycle that lay wholly below the Sun, she would never appear, not merely full, but not even exactly halved.

What is more, through the telescope she would never appear smallest when she becomes full, nor largest when horned, unless she were full in her highest position and horned in her lowest. I say "through the telescope", however, because otherwise, to the naked eye, she appears nearly as large when she is not far from conjunction beyond the Sun as when she is not far from conjunction on this side of the Sun. For, radiating all round with a spurious light (as do all luminous things seen from afar and out of darkness), although there she is small in her disc, she nevertheless shines out whole all round; here she is nothing but a thin sickle, which nevertheless — because it is, besides, a portion of a greater disc — brings it about that Venus is then seen in the daytime, she who in the same way cannot be seen in the daytime so long as she is full.

As regards Mars, however, and Jupiter and Saturn, they do not by turns go direct and really turn back their course. Rather, they — who, if they were viewed from the Sun (and from the Earth too, if it were at rest), would be seen always to proceed in the order of the signs — must necessarily, to us, who within their circuits, and indeed more swiftly than they, in a circle mo- ve; it is necessary, I say, that they appear to regress [Regredi] whenever we pass by toward the same region, having come close to them, and have the Sun on the other side — as if, that is, by thus overtaking them and soon thus leaving them

at our back, so that our sight refers them no longer to following fixed stars but to preceding ones.

Conversely, however, it is necessary that they appear to go direct [Dirigi], or to move in the order of the signs, whenever we go in opposite directions and the Earth advances in such a way that it has the Sun and them on the same side, and our sight refers them to following fixed stars.

Finally, it is necessary that they appear to stand still [Stare] whenever we pass from the opposite region into the same one, or from the same one into a different one; because the Earth then moves in such a way that our sight refers them for some time to the same stars. All of which can be understood even from inspection itself of the system depicted earlier, and from imagining the motions along their own circles.

FIFTHLY, since it is accordingly a marvel that these planets always become retrograde [Retrogrados] in opposition with the Sun and direct [Directos] in conjunction, never in other places or at other times, and since the common opinion cannot state the cause why this happens, this one nevertheless states it excellently, from the arrangement of the system, according to which it is altogether necessary that the thing appear to happen in this way and in no other.

What is more, it at the same time excellently states the cause why these three planets are so large in opposition, or at the time when they are acronychal [Acronychi], compared with the other times: namely, because the Earth then passes them most closely.

Likewise, why in Saturn the retrogradations [Retrogradationes] are more fre- quent than in Jupiter, and in the latter than in Mars: namely, because the Earth overtakes Saturn, the slowest, more often than Jupiter, which is a little swifter; and Mars, the swiftest of all, as more slowly, so less frequently.

Why, conversely, the arc of retrogradation is greater in Mars than in Jupiter, and in the latter than in Saturn: namely, because the retrogradation of Mars, on account of its nearness, begins closer and ends farther away than in Jupiter; and for the same reason in the latter than in Saturn; and so on for the others.

FINALLY, since the other planets appear retrograde and stationary [Station- arij], to what end should we think that this does not apply to the Moon and the Sun? Unless because the Moon is indeed carried round us, wherever we are, as if about a centre, whereas the Sun is itself the one about which we ourselves are always carried round; and it cannot fail to appear always to proceed in the order of the signs, toward the part opposite to us?

CAPVT VII.

Chapter 7.

Quæ viſa demùm magis congrua ad motum Tertium inducendum.

The things that at length seemed more fitting for introducing the third motion.

As for, finally, the third motion — or, if you prefer, that continuance [continentiam] in the parallelism of the axis which has been set out — the devising of it was, FIRST OF ALL, necessary so that the alternation of days and nights, and of summer and winter, might be observed.

Namely, if, with the Earth carried through the zodiac, the equator conceived in it, together with the ecliptic, into the same pla- ne coincided, and its axis became parallel to the axis of the ecliptic, every part of the Earth would perpetually have its horizon in the same situation with respect to the Sun itself; and accordingly the Sun would never rise or set, but would either perpetually appear or perpetually be hidden; and, besides, it would never appear either to be raised or to be lowered; and so no variation would be brought about either of days or of seasons.

But with the Earth's equator cutting the plane of the ecliptic, and its axis remaining constant in its parallelism with itself, it comes about that the horizon of each place changes its situation with respect to the Sun itself; and not only does it make sometimes day, sometimes night, because the Sun is now presented, now withdrawn, but also, for us who live, for example, toward the north, the swelling of the Earth stands in the way, so that, while the Earth is in the northern signs, we do not have the Sun as high and as open as while it is in the southern ones; and so we do not have days so long, nor feel heat so intense. This can be understood very easily even from the mere placing and carrying round of the small globe already mentioned over the zodiac of an ordinary sphere (the parallelism always being preserved, and a point being marked on the small globe to represent the situation of Paris [Lutetiæ]).

SECONDLY, so that it may be made clear how the height of the pole [Poli altitudo] remains the same, or unvaried, at each place on the Earth.

Namely, when the Earth is in Cancer, it seems natural to suppose that the north pole ought to appear to us much higher than when it is in Capricorn. But in truth, from this parallelism it is brought about that equally hi- gh, wherever the Earth may be, it appears. The matter, however, is to be conceived in this way.

Let the figure set out in the third chapter be repeated in this place; and let it be understood that E G, the axis passing through the Sun,

Diagram. A woodcut filling the width of the text block. A large circle; across it, a dotted line runs from B on the left to D on the right, sloping slightly downward to the right and more heavily dotted toward D. Inside stands a smaller circle, with E at its top and G at its foot. A straight solid line runs from lower left to upper right inside the small circle and carries five small globules, each with a cross of diameters drawn through it: the lowest stands on the small circle's left side beside I, the uppermost on its right side beside K, and the middle

one sits on the dotted line between L (above and to the right) and M (below). A set of dotted lines crosses the figure from the letters above the large circle to the letters below it, most of them nearly parallel and slightly inclined; one dotted line runs diagonally from the top left down to the bottom right, crossing the others. At the top, a straight line runs below the arc from about the dotted line under P to near T; at the bottom, a straight line runs above the arc from about Q toward V. Which upper letter's line ends at which lower letter has not been traced line by line. No Sun is drawn or labelled. A small curled mark on the dotted line between the fourth globule and H is not resolved as a letter [?].

- N (above the large circle, top left, beside the upper end of a dotted line)
- P (above the large circle, right of N)
- R (above the large circle, right of P)
- A (above the large circle, right of R)
- X (above the large circle, right of A)
- T (above the large circle, top right)
- B (at the left end of the dotted horizontal line, on the large circle)
- D (at the right end of the dotted horizontal line, on the large circle)
- E (above the small circle, at its top)
- F (left of the small circle, just outside it, above the dotted line)
- L (above and to the right of the middle globule)
- K (right of the uppermost globule, outside the small circle)
- H (right of the small circle, just outside it, below the dotted line)
- I (left of the lowest globule)
- M (below the middle globule)
- G (below the small circle, at its foot)
- Q (below the large circle, bottom left)
- S (below the large circle, right of Q)
- C (below the large circle, right of S)
- Y (below the large circle, right of C)
- V (below the large circle, right of Y)
- O (below the large circle, bottom right; round, with no tail, and set smaller than the other letters)
- [?] (a small curled mark on the dotted line between the fourth globule and H)

is produced on either side as far as the region of the fixed stars, and ends at the points A C, which are to be called the poles of the world [Poli Mundi].

Let us also understand that the axis of the Earth, continued on either side to the fixed stars, is successively P Q, R S, etc., and describes, by its annual carrying-round about the axis of the world,

a surface, cylindrical or columnar, whose bases are two circles described about the poles, having as their diameters the lines P T, Q V, equal to the diameter F H of the Great Orb.

Let us understand, again, that the distance from the Great Orb as far as the fixed stars is so great that this column, viewed from here and seen to decrease

continuously (in the way that all parallels produced lengthwise usually do), appears at last to end in a point at either end, and those two bases, or twin circles described about the poles, are taken as points.

From this we shall at the same time understand that wherever the Earth has stood in the zodiac, or Great Orb, the pole standing above the horizon remains the same, or appears of unvaried altitude. For although the axis of the Earth looks toward now one, now another part of the heaven about the pole of the world, the interval between all these parts is nevertheless as a point to the sight, and the whole compass of the circle described about the pole is reckoned as the same pole.

THIRDLY, to explain how it comes about that the same stars are always vertical, and appear of the same magnitude.

For since, if some stars pass to our zenith while the Earth is in Cancer, those stars would seem not to be going to pass to the zenith in the same way, nor to be going to appear as large, when it is in Capricorn.

Indeed, just as the altitude of the pole, as was said just now, stays the same because of the parallelism already mentioned, so it is necessary that, because of that very parallelism, the st-

ars that are vertical remain the same, inasmuch as they always keep the same distance from the pole itself.

And it is indeed true that, when the Earth is in Capricorn, our zenith is directed to a point of the region of the fixed stars as far distant [tandùmdem] [recte: tantùmdem] from the point to which it is directed while the Earth is in Cancer, as is the distance between the very tropics of the Great Orb. But if this whole orb is like a point when compared with the whole region of the fixed stars, a fortiori a small portion of it will be so — namely the distance between the tropics.

For this reason it comes about from this that the same parts of the region of the fixed stars do not indeed in reality correspond to the zenith at one place and another; yet the same parts nevertheless correspond to it as far as the senses can tell: nor should it be a wonder if the same stars, which are perceptible parts of the heaven, remain constantly vertical.

Moreover, it also comes about that the very magnitude of the stars appears unvaried, because wherever the Earth is, it is viewed as if from the same point.

FOURTHLY, to show the precession of the equinoxes which was described above, or that slow motion toward the east which is attributed to the eighth sphere, or firmament.

For the stars of Aries do not seem to have receded already from the equinoctial point by nearly thirty degrees within two thousand years for any other reason than because they have in reality advanced in the order of the signs.

And yet, because the same thing will appear whether the stars in reality recede from the equinoctial point in the order of the signs, or the equinoctial point itself recedes from the stars against the order of the signs, for that reason Coperni-

cus assumed that this motion of inclination, or continuance of the axis, so occurs that it does not exactly follow the motion of the centre; and that it accordingly makes the equator cut the ecliptic each year somewhat on the nearer side, and so produces the equinoctial point in a somewhat preceding part of the ecliptic.

From this, too, it would come about that, while the equinoctial point passes against the order of the signs (from which this motion was called by him the Precession, or Anticipation, of the equinoxes), the parts of the ecliptic left behind, and so the stars of Aries and others, appear to pass just as far, or to advance in the order of the signs.

What he subsequently added, partly to save the inequality of such a motion of the precession of the equinoxes, partly the variation of the obliquity, or of the greatest declination of the ecliptic (while for that purpose he wished it to suffice that the terrestrial axis should describe the shape of a twisted little garland, of this form, 8, in that by going toward the east and returning toward the west an acceleration and retardation of that motion would come about, and by going toward the north and returning toward the south an increase and decrease of that declination would be produced) — what, I say, he added on this matter is not necessary to mention, for this reason: that the observations of either phenomenon are too uncertain for anything to be duly established about them, or for it to seem that one should dwell on them.

Let it be enough that it seemed more fitting to refer these things which have been related up to this point to the little globe of the Earth itself, rather than either to the Sun or to the immense sphere of the fixed stars.

But shall I add, FIFTHLY, that it seemed more fitting to Galileo to explain the tide, or the flux and reflux of the sea, partly from this motion and partly from the preceding ones, rather than to refer it to the influence of the Moon, or to any other cause devised so far?

For just as water contained in a vessel, and fleeing back when the vessel itself is carried along, does not stay as if heaped up, but flows back forward, if the carrying is done non-uniformly; so he held that the sea, contained in the cavities of the Earth and fleeing back toward the west while the Earth itself is carried toward the east, does not stay put, but flows back and again reciprocates, if it happens that its vessel, as it were, is itself carried non-uniformly.

Moreover, he proved that it is carried non-uniformly from the fact that, although each of the three motions is uniform in itself, their mixture nevertheless brings it about that any given part of the Earth's surface one takes is moved non-uniformly.

For the part in which the Mediterranean Sea lies, for example, is swept so constantly toward the east by the annual motion that meanwhile, being revolved by the diurnal motion, it has half of this revolution agreeing with the annual motion and half disagreeing with it; and so, while both motions conspire, it is carried more swiftly toward the east; while only the one tends that way, it is carried more slowly; and twice on any day it is carried uniformly

— namely once while it passes from swiftness into slowness, and once while it passes from slowness into swiftness.

Accordingly, he held that from this non-uniformity there arises the reciprocation of the tide, twofold and occurring on each single day.

Thus, moreover: since the diurnal motion is never made obliquely, but always directly toward the east, on account of the parallelism mentioned; and since meanwhile it is aided, or advanced, by the annual motion, which is made obliquely, less around the equinoxes, on account of the obliquity, than around the solstices; for this reason he judged that, because of the supervening non-uniformity of this kind, the tide is intensified at both those times; and at the equinoxes, indeed, most of all, on the ground that the annual motion is then more opposed to the diurnal.

Thus also: since, if it is true that the Earth is carried through the zodiac by the solar rays, and that the Earth itself, besides, carries the Moon along with it as its appendage, the carrying of the Earth must be intensified and relaxed according as the Moon is new or full — that is, standing there on the near side of the Earth itself, here beyond it — in the same way in which the vibrations of a hanging ball, or of one suspended from a cord and swinging to and fro, are intensified or relaxed according as a little ball is hung on along with it either above or below; for this reason he thought that from this new inequality it comes about that the tides turn out more intense at the new moons and full moons than at other times.

Thus again: since from the Moon and the Earth, carried together, there comes to be one moving body [mobile], as it were; and since, on account of the Moon's special motion, this total moving body does not reach the meridian on each single day except later by nearly one hour, or by four-fifths of an hour; for this reason it can come about that the tide becomes more retarded on each single day by nearly one hour, or four-fifths.

We must pass over, however, the point that the other variations which occur in the tide of the sea can, not unsuitably, be referred to the situations and conditions of the shores.

CAPVT VIII.

Chapter 8.

Quid Copernicani ad ea, quæ obijci ſolent ex Aſtronomia reſpondeant.

What the Copernicans reply to the things that are usually objected from astronomy.

NOW, since the kind of arguments that are usually objected against the motion of the Earth is threefold — for some are drawn from astronomy, some from physics, some from Sacred Scripture — there is no reason why we should dwell much on those that are chiefly astronomical, since the way in which the

Copernicans reply to them is, for the most part, clear from what has already been said.

For what is usually objected, for example — that it would come about that neither would the height of the pole be constant in the same place; nor would the same stars be vertical and be held to be of the same magnitude; nor, if the motion were made along the ecliptic, would any variation of days and nights, and of seasons, occur; nor would any motion of the fixed stars in the order of the signs be observed; and whatever objections there are of this kind — that was explained just before.

Moreover, as to what is pressed, besides, FIRST OF ALL — that it would come about that a whole hemisphere, or half of the heaven, would not appear, and so that six signs of the zodiac could not be seen at all times, unless the Earth dwelt at the centre:

They reply that, wherever within the compass of the heaven the Earth may be, that which, of the heaven, will stand out above the horizon, or above its plane, will appear to the eye as if a

whole hemisphere — unless we are so few fathoms [orgyijs] away from the vault of the heaven that the vertical point and the surrounding points are discerned to be less distant from us than the horizon itself, or that extremity which will be visible from the earth. Namely, the eye, having the heaven as if contiguous on every side to the very extremity of the Earth, measures the height of the vault by no other semidiameter than the very breadth, or distance, of the horizon.

The Earth, moreover, they say — whether it is conceived as raised from the centre to the surface of the Great Orb, or as carried from the Tropic of Capricorn of the same orb into the Tropic of Cancer — does not for that reason come so near to the very vault of the heaven that we are less distant from it than from the very horizon of the Earth. What is more, they say, according to what was said before, it does not even turn out more advanced toward that vault by any sensible point, so that on that account we should see something less than a hemisphere of it, or that less than six signs of its zodiac — that is, than 180° [centrum octoginta gradus] [recte: centum octoginta gradus] — should appear above the horizon.

As to what is urged SECONDLY — that it would come about that the Sun could not be called apogean, perigean, and other things:

They reply that it can always be said, on the ground that this astronomy does not strike out the accepted terms, provided they are understood to be used according to the things that appear; and no prejudice is on that account done to the existence of the thing that is in reality. For, they reply, the Copernicans themselves also commonly say that the Sun rises, sets, is in some sign, and the other similar things — speaking, that is, according as things appear.

It will therefore be permissible to say that the Sun is apogean,

when the Earth will be aphelial, or most distant from the Sun; and perigean, when it is perihelial, or standing closest around the Sun. For the former will

belong to the Sun in appearance, the latter to the Earth in reality, inasmuch as the Earth's orbit will be eccentric, or not so much a perfect circle as a certain ellipse, in one of whose foci, or centres, the Sun is, and the Earth accordingly approaches it now more, now less.

That is to say, the paths of the planets (namely those which they describe with their bodies through the ethereal spaces, even while they are supposed to be carried, and carried back, through eccentrics and epicycles) have been observed to be elliptical, in roughly the same way as was intimated concerning the Moon in the previous book; although, since the ease of calculation so requires, the ellipses may also be understood to be reduced to eccentrics and epicycles.

As to what is added THIRDLY — that it would come about that neither would the aspects of the planets be the same, nor their latitudes, nor, in particular, would the phases of the Moon, and its eclipses and those of the Sun, appear in the same way, etc.:

They reply that these and the rest will appear exactly the same; since, although it is the Earth itself that in reality describes the ecliptic, the Sun nevertheless is going to appear to describe it; and the other planets, while they run through the zodiac, are to be seen to be variously configured with it, and among themselves, and to depart from the ecliptic, or to acquire latitude.

And since the Moon will always be carried around the Earth in its own orbit, which cuts the ecliptic in the same way at opposite nodes, it will undergo its phases exactly in the same way; and, appearing in the same way conjoined with, or opposite to, the Sun, in the same way

will suffer an eclipse, or not suffer one, when it is in opposition; and in the same way it will produce one in the Sun, or not produce one, when it is in conjunction — without any difference.

As to what is subjoined FOURTHLY — that it is laughable for the Earth, the dregs of the elements, to be thought a celestial body and to be reckoned one of the planets:

They reply that the Earth is no more to be reckoned the dregs of the world than Mars, or any other planet. For, they say, even though it lacks light, the others nevertheless lack it too; and if the others shine with the light of the Sun, the Earth itself likewise shines with the same light as well.

That it is not less globular than they are, so that it is accordingly just as able to be carried around through the ethereal spaces. That it is not of an incongruous bulk, since, as it is smaller than some, so it is larger than the rest.

And that, though it has an uneven and roughened surface, nevertheless the Moon itself has one too, as is proved by the telescope; and that the others too have one is not improbable, if only from the fact that they reflect the light of the Sun to us from more than one point of themselves; and, besides, that they shine dully and do not twinkle in the manner of the fixed stars — as though the greater part of their rays were deflected, on account of various windings, elsewhere than toward us.

Indeed, that even though generations and corruptions take place on the Earth, it cannot be proved that they do not take place similarly on the others; although we see them no more than those that take place on the Earth could be seen from the Moon and the others.

That if they do take place, the others cannot on that account be reckoned imperfect: since imperfection is, indeed, the capacity

for some one thing to be corrupted, or to cease to be; but not the capacity, while remaining unharmed, to bring forth, out of the corruption of certain things, other and still other things. That, surely, to bring forth this so great elegance of flowers and of other things is a far greater perfection in the Earth itself — since it does so without any loss to its bulk — than if, immune from corruption, it continued without any change at all of its surface.

Moreover, that not only do the Earth and the Moon exchange roles, while they darken and illuminate each other in turn; but also, whatever Venus or Mercury appear to the Earth, the Earth appears to Mars, Jupiter and Saturn. And that whatever Mars, Jupiter or Saturn appear to the Earth, the Earth appears to Venus and Mercury: that is, as regards its motion and its shape; as regards the variation of its size, as regards its phases, and the rest.

As to what is reckoned, FIFTHLY, inelegant — to hold that distance of the fixed stars from the Earth to be so immense that this whole Great Orb must be treated as a point:

They reply that, since there is no reason, nor any observation made by the senses, which proves the distance to be smaller; and since, on the other hand, with that distance supposed, all the phenomena are saved more elegantly than when a smaller one is supposed, according to the common opinion; for that reason it does not seem that the distance is rightly thought inelegant.

For as to so great a vastness being, indeed, reckoned superfluous: that those who think so seem to do injury to the magnificence of the supreme Maker, while, not grasping

to what end God made so ample a world, they bring His power and wisdom down to the measure of their own comprehension, and, so to speak, to the narrow limits of their own parsimony.

As to the LAST point — that the Sun would therefore be smaller than any visible fixed star; since, if the whole Great Orb cannot be seen from the fixed stars on account of its slenderness, the Sun, held merely to be, as it were, its centre, would be far less visible:

They reply that the Sun may nevertheless not be smaller; and that, though it be smaller, it can nevertheless still be seen from the very region of the fixed stars: because, just as the little flame of a lamp, seen from far off out of the darkness, is dilated into a very ample appearance, so the little discs of the stars are dilated through the darkness of night — discs which, without such dilation, would be purely invisible little points.

And that hence it would also come about that the Sun, viewed out of the darkness, would be amplified in the same way, and would be rendered visible

like a star; however much, without an amplification of this kind, it would turn out to be a completely invisible little point.

CAPVT IX.

Chapter 9.

Quid ad ea, quæ ex Phyſica.

What to the things from physics.

NOW, among those from physics, the FIRST is this: that the lowest place, such as the centre, or middle, of the world is, is due to the heaviest body of all, such as the globe of the Earth is.

But they reply: first, that according to the mind of Plato there is indeed in the world an extreme and a middle;

but that the extreme is not on that account reckoned the Highest, nor the middle the Lowest. For, they say, "highest" and "lowest" are said only comparatively, or with regard had to the position of the parts of an animal, and, indeed, most of all of a human being; for whom, wherever in the world they may be, that is higher, or upward, which is beyond the head; and that lower, or downward, which is beyond the feet.

Next, that the parts of the Earth indeed are, or can be called, heavy, inasmuch as they are carried toward the Earth as toward the whole, whose integrity depends on the union of its parts; but that the whole Earth, in itself, is neither heavy nor light, any more than the Moon, Venus, or any other of the celestial globes, whose parts likewise, if they have been torn away by some force, will each seek their own globe again by equal right, and will be able to be reckoned heavy in the same way.

Moreover, that there is indeed in the Earth a centre, or middle, toward which heavy things are carried by accident (by accident, I say; for of themselves they are carried only toward the body of the Earth, with which they seek to be united; and meanwhile they do this along the shortest line, which at the same time happens to look toward the centre); but that the Earth's centre is not on that account the same as the centre of the world; and that heavy things can accordingly tend toward its centre wherever in the world the Earth may be.

SECONDLY, this: that to a simple body, of which kind the Earth is, a single [?] simple motion is appropriate. And that therefore, since straight motion belongs to the Earth — and that downward (as the motion of its parts indicates) — circular motion does not belong to it.

But they reply, in the first place, that it is false that the Earth is a simple body; experience rather teaches that it is variously compounded of things so very heterogeneous.

Next, that not even to a simple body is a variety of motions repugnant, provided these are not toward parts opposite at the same time, but are among

those that conspire toward the same part, or region; as has already been said of the globe rolled upon a plane.

Moreover, that what belongs to a part does not on that account belong to the whole, if it belongs to the part as it is a part; for otherwise a whole human being would have to be round, because the head is so. And therefore also that it is not necessary, from the fact that the parts of the Earth are carried straight, that the whole Earth be carried straight; since straight motion belongs to its parts so that they may be united with it, whereas the Earth as a whole does not seek union with any other thing.

Lastly, that although straight motion is proper to the parts of the Earth, yet the motion of the whole, that is, circular motion, belongs to them at the same time, inasmuch as, while they fall, they are meanwhile carried across together with it; in the way in which, to the hand, besides its own motions — up, down, forward, backward, round in a circle, etc. — there belongs at the same time the motion of the whole body, with which, as the body walks, the hand is meanwhile carried across.

THIRDLY, this: that the Earth would be scattered by so rapid a motion; and that we ourselves, carried across so rapidly, would not endure the air cut through by us and made, as it were, into an intolerable wind.

But they reply: first, that the Earth is strong in a magnetic force, by which it holds all earthly things bound together (in the way, namely, in which the Magnet holds all magnetic things, as pieces of lodestone and of iron); and that earthly things attracted in this way are called heavy, not so much by an inherent quality as by a power impressed by the Earth; whereas those things are reckoned light which are less heavy, or are drawn less, and yield place to heavier ones — not so that they are altogether torn away, but only so that they are more remote, or more outward, and cohere with the nearer, or more inward, ones through those in between.

Next, that the Earth is not scattered, for this reason: that just as it holds all its parts, from the innermost right out to the outermost, by its magnetic force, so it moves itself and carries them along with it, with a motion swift indeed, but nonetheless uniform, even and calm; and not in such a way that it either jolts, or strikes against something, from which, being shaken, it would dislodge its parts, or drive them away from itself, and throw them forward elsewhere than where it is itself heading, and faster.

Moreover, that because the Air too is, from what has been said above, of earthly matter, and clothes the more solid globe itself all round like down, it is for that reason carried round together with the Earth in such a way that we, living within it and carried across together with it, do not cut through it, nor feel it made, as it were, into a wind.

And finally, however, that since the Air is of a more fluid substance, and is not swept along as swiftly as the solid inner globe, from this, it seems, comes the reason why under the equator, and round about it, where the motion of the Earth toward the east is swiftest, the air so resists, and goes, as it were, toward

the west, that sailors experience it as a wind, as it were, both unceasing and even.

Not to say anything about the Sea, which on account of its own fluidity too, flows somewhat retarded, and from its own piling up, or from the obstruction of the shores, flows back, as we touched on a little earlier.

FOURTHLY, this: that no body, whether sent upward or let fall from above, would fall perpendicularly, if, while it was in the air, the place of the Earth over which it hung were drawn away from under it in just the way that, while a ship is carried across, the stern from which an arrow sent upward was sent is drawn away from under that arrow.

But they reply, first, that it is false that an arrow sent straight upward from the stern does not fall back onto the stern, however much this has been objected up to now — but by those without experience, of course. Namely, that the cause is that the ship impresses its motion on all the things that are carried by it, and, through their intervention, on all the movable things which they themselves send or let fall. And that from this it comes about that, while the bow impresses on the arrow a motion upward, it impresses at the same time a motion forward, which the bow itself meanwhile has from the ship, or from the man carried across by that same ship; and that thus the arrow, while it is in the air, always hangs over the stern, and at length falls back onto it, on account of a motion of this kind.

Moreover, that the case is similar not only when someone throws a stone from the heel [pterna], or foot, of the mast into the masthead [carcheſium], but also when he lets a stone fall from the masthead onto the heel. For that stone, let fall on the stern side, is neither left behind by the mast, nor, let fall on the prow side, overtaken by the mast; but it falls onto the heel just as if the ship were at rest. That is, because, although the one letting it fall applies no motion of his own, he nevertheless impresses the ge- neral one, which he has, impressed on him by the ship, with the mast intervening. And from this it comes about that one letting a stone fall on the stern side draws it back toward the mast, which is meanwhile running off, by just as much as the motion of the mast itself amounts to; and one letting it fall on the prow side throws it ahead of the mast, which is meanwhile following, by just as much as the motion of that same mast amounts to.

Accordingly, that the example objected can be turned back in such a way that the Earth in like manner impresses its motion on all the things carried by it; and that a stone sent upward falls back onto the same place of the Earth for this reason: that the one throwing it impresses on it not only his own force, by which he drives it upward, but also the force which he has from the Earth, and on account of which the stone is carried forward by just as much as the Earth itself; and that thus, while it is in the air, it always faces the same place, and falls onto the same place.

In this same way, a stone let fall from a Tower falls onto the place over which it hangs; because, although the one letting it fall does not apply a motion of his

own, he nevertheless impresses a motion which has been impressed on him by the Earth, with the tower intervening.

Next, that — just as the motion of an arrow, or of a stone, sent or let fall from a ship is not in actual fact straight, but bent, and along the line which they call Parabolic, and yet appears straight, or perpendicular, to all those who are in the ship, since the eye does not perceive the motion by which it is itself carried, and which is common to the arrow and to the stone, but only that which is impressed in addition — so the motion of a stone sent upward from the Earth, or let fall from a tower, is indeed not truly straight, but is very much bent through the spaces of the World, and is that of a most open Parabola; and yet appears straight, or perpendicular, to all who are carried along by the Earth; since in like manner the eye does not perceive the motion by which it is itself meanwhile carried by the Earth, and which is common to the stone also, but only the other one, which has been impressed on the stone in addition, either by the thrower, or by heaviness, or attraction.

That there is only this difference: that some can stand outside the ship who observe as bent the motion seen as perpendicular by the sailors; but no one is able to plant a foot outside the Earth so as to detect as bent that motion which seems perpendicular to the Earth-dwellers themselves.

FIFTHLY, this: that a cannon-ball fired toward the west would carry farther, as though the gun would at the same time be following toward the east; and again, that fired toward the south, or the north, it would always stray from the target by just as much as the target, while the ball was in the air, would be carried toward the east.

But they reply, First, that — just as two people playing ball together on the thwarts of a ship do indeed impress an equal force on the ball, so far as lies in them; hence also, relative to the parts of the ship, the ball covers as much space toward the prow as toward the stern; but the one who is on the stern side adds the ship's motion to his own, and the one who is on the prow side takes it away; and from this it comes about that the ball sent toward the prow covers in addition as much space of air as the fellow-player at the prow is meanwhile carried off while the ball is in the air; and that sent toward the stern it covers so much less, by as much as, while the ball is in the air, the fellow-player at the stern draws near to it — in exactly the same way, if there are two guns, one toward the east, the other toward the west, aiming at each other in line with equal forces, just as much space is covered over the surface of the Earth by the ball fired from either one. For although the ball fired toward the east has a force added to it by the Earth, and the one fired toward the west has it taken away, yet meanwhile the gun which fired toward the east follows the ball by just as much as it impressed on the ball of the motion received from the Earth; and the one which fired toward the west is carried off from the ball by just as much as it took away from the ball of the motion received from the earth. And so, with the addition and the subtraction made to compensate each other, the ball is carried forward over an Earth in motion just as over one at rest.

Next, that a ball directed either toward the north or toward the south strikes the target just as if the Earth were at rest; because, while both the gun and the target are carried toward the east, the ball also, passing across through the air, is carried at the same time, on account of the force added to it by the Earth; and by this force it comes about that these three — gun, target, ball — are always kept within the same straight line.

LASTLY, this: that clouds, birds, and the other things hanging in the air would always appear to be carried very rapidly toward the west.

But they reply, First, that — just as one who leaps across the thwarts of a ship has, while he is in the air, not only the motion proper to himself, but also the motion impressed by the ship, by which he is carried across together with the ship, in whatever direction he may leap by his own motion — so a bird, for example, while above the surface of the Earth, and through the air flutters, has, besides its own motion, also the general one impressed by the Earth, by which it is carried across together with the Earth, in whatever direction it may itself meanwhile flutter, or however it may hang in the air, or seem suspended. And the same must be said, in proportion, of a cloud and the rest.

Next: just as the ship's motion is impressed on one leaping across the thwarts of a ship at the moment when his feet are lifted, so the Earth's motion is impressed on birds at the moment when they first rise from the Earth, from a tree, or from some other thing clinging to the Earth and carried across at the same time; and moreover that it is repeated, and as it were driven in, as often as birds beat the air with their wings so as not to fall perpendicularly, or onto the place of the Earth over which they hang. Namely, the air too, carried across with the Earth, serves as a prop, resting on which they may renew their motions, as benches placed on the thwarts can be, across which that man may leap about.

Finally, that, so that the matter may be better grasped, fish are to be considered within water contained in a tub which a ship carries across. For just as the fish are carried across together with the water by the general motion of the ship, and yet meanwhile either hold still, or are moved this way and that in various ways within the tub, just as if the water were at rest and were not being carried over with the ship; so birds, and whatever other things are in the air, are carried across by the general motion of the Earth in such a way that they either hold still, or are moved through the air in any direction whatever, just as if the air were at rest and were not being carried across with the Earth.

CAPVT X.

Chapter 10.

Quid ad ea, quæ ex S. Scriptura.

What to the things from Holy Scripture.

FINALLY, the passages of Sacred Scripture that are objected are of such a kind that they seem to assert the rest of the Earth, partly expressly, like this one, *The Earth stands for ever*; and, *You founded the Earth upon its own stability*, etc.; or tacitly, inasmuch as motion is attributed not to the Earth but to the Sun, like this one, *The Sun rises, and sets*; and, *The Sun went back ten lines*; and, *Sun, do not move against Gabaon* [Gibeon], etc.

But those men reply, in the first place, that the aim of Sacred Scripture is not to make people either Physicists or Mathematicians, but to render them pious, and prepared for salvation, or for supernatural grace and glory. And therefore that it also speaks of things insofar as they appear to all people commonly, so that, since their own salvation concerns everyone, it may be understood by all.

That accordingly Scripture itself cares little what things are like in themselves and in truth; since, for people who are to be instructed toward salvation, the common notions of things are in any case sufficient.

Namely, that unless we explain most passages in this way — that is, unless we say that Scripture has lowered itself to the grasp of the common people, or that the Sacred Writers have tempered themselves and accommodated themselves to an unlearned people — we shall be far from the genuine sense in which the Holy Spirit willed it to be understood.

And lest far from the argument which is at hand, one should stray: that Sacred Scripture reckons it of little concern whether the Earth, compared with the Heaven, is a point or not; and therefore that it speaks of the Heaven and the Earth as of two notable parts of the World, since they seem to be such, while the Heaven appears as a vault, and the Earth as the floor of the World's building. And again, that it is of little concern whether the smallest stars shining in the Firmament are greater luminaries than the Moon or not; and that for that reason it speaks of the Moon as of a great luminary second to the Sun; since the Moon, however much smaller it may be, and less bright in itself, than the stars, yet on account of its nearness appears both greater and illuminating with ampler light.

In the same way, therefore, that Scripture reckons it matters little whether the Earth moves and the Sun, for its part, is at rest, or not; and therefore that it speaks of the Earth as being at rest, since it appears to be at rest, and of the Sun as moved, since it appears to be moved, there being no one to whom it does not so appear.

And therefore that those latter passages too are indeed disposed of in a few words: namely, that the Wise Man, when he said *that the Sun rises, and sets*, aimed only to signify the alternation that appears in the rising and setting of the Sun, whether it were, further, the Earth or the Sun by whose motion it came about. And that the Prophet, when he said *that the Sun went back ten lines*, wished nothing else to be understood than what had appeared, whether a going back of the Sun or of the Earth had brought it about. And that the Patriarch, when he commanded *the Sun not to move*, took care only of this, that the Sun

should appear to stand still above the Earth, whether in the end it was the Sun or the Earth by whose standing this was achieved.

That it can be added, concerning the former passages, that they seem to be meant to be understood;

not of the standing which is opposed to motion, but of that which is opposed to dissolution, or corruption.

And since those words especially, *The Earth stands for ever*, are on everyone's lips, that it is to be noted that the whole passage stands in these words: *A generation passes away, and a generation comes; but the Earth stands for ever.*

Namely, just as, while various seals are applied to a lump of wax, various shapings come about; and while some pass away and others come on, or some of the shapes are effaced and others succeed in their place, the lump of wax nevertheless is not corrupted, or is neither diminished nor increased, but continues the same: that so, it seems, the passage is to be understood; that although various generations have come about on the Earth from the very beginning of the World, and still come about, and are to come about hereafter, yet it is not on that account the case — while generations pass away and come, or some forms of earthly bodies perish and others are brought in in their place — that the very mass of the Earth is corrupted, or increased, or diminished; but that it constantly persists the same, and is still as great, and will be hereafter, as it was from the very beginning.

Accordingly, since this seems to be the genuine interpretation of an especially celebrated passage, that from it there seems to be asserted of the Earth not so much a fixity in place as a constancy in its integrity.

Here the Sentence of the Congregation [Congregrationis] [recte: Congregationis] of Cardinals placed in charge of the Inquisition, who condemned this opinion about the motion of the Earth in Galileo, is usually pressed:

But the Orthodox reply (for the Heterodox make shorter work of the matter) that that sentence was a special one, or concerned Galileo in such a way that it could have special grounds against him which would not hold against others. They add that that sentence is indeed of very great weight; but that it is nevertheless not on that account necessarily to be held as an article of faith, of the kind that those are held to be which have been established by general Councils. They go on to say that it does not seem, at least until it has been promulgated — that is, legitimately prescribed — as some dogma of the Faith, to bind all the Faithful. Finally, they declare that, if it is once legitimately prescribed, they are prepared to recant.

And thus those men, for their part, usually defend themselves.

CAPVT XI.

Chapter 11.

Quid de Siderum à Terris diſtantia, & magnitudine definiant.

What they determine about the distance of the Stars from the Earth, and their magnitude.

SINCE we have seen through, partly from the arguments, partly from the exceptions, or replies, of the Copernicans, how they try to save all the Phenomena, hardly anything else remains here than to record in a few words what distance from the Earth, and what magnitude, they attribute to the individual Stars.

And Copernicus himself, indeed, content to say that the Sphere, or region, of the Fixed stars is so distant from the Earth that the Great Orb, compared with it, is to be held as though a point, did not, besides, apply a measure by which anything more specific about this distance might be pronounced by him. Content also to speak of the magnitude of the Sun and of the Moon (namely, that the Sun is greater than the Earth about 162 times, and the Moon 43 times, very nearly), he said nothing similar about the magnitude of the other Stars, whether Wandering or Non-wandering.

But fifteen years ago Philippus Lansbergius [Philips van Lansbergen] came to the rescue; who, just as he defined the distance and magnitude of the Planets relative to the Earth, so designated both the distance and the magnitude of the Fixed stars relative to the Great Orb, which he also called the Sphere of the Earth.

As regards, therefore, the Distance first: concerning the Planets, indeed, he laid it down in this manner.

Mean distance, by which they are removed from the Earth		is, in terrestrial Semidiameters
	Moon	59
	Mercury	1500
	Venus	1500
	Sun	1500
	Mars	2275
	Jupiter	8091
	Saturn	14880

Of the Fixed stars, however, having supposed the semidiameter of the Great Orb to be of 1500 terrestrial semidiameters, he also supposed that the parallax of the Fixed stars with respect to the Great Orb hardly exceeds one eighth, or a ninth part of a minute; and accordingly he declared that the Fixed stars, or the sphere of the Fixed stars, are distant from the Earth by 28,000 semidiameters of the Great Orb; or, if you prefer, by 42,000,000 terrestrial semidiameters.

As for, next, the Magnitude itself: he supposed first, concerning the Planets, that the apparent diameters were: of the Moon, indeed, about 33′; of the Sun, about 35′; of the others, none other than the one recorded above from al-Battānī and al-Farghānī.

Concerning the Fixed stars, however, on account of the telescope, by which the spurious light is cut away from them, he held their diameters to be smaller than they were commonly thought to be: namely, of stars of the first magnitude, 1′; of the second, 40″; of the third, 30″; of the fourth, 20″; of the fifth, 10″; of the sixth, 4″.

Hence he also judged thus about the magnitude of the Planets.

They are			times than the Earth.
Moon	smaller	45½	
Mercury	smaller	12	
Venus	smaller	3½	
Sun	greater	434	
Mars	smaller	8	
Jupiter	greater	25⅖	
Saturn	greater	46⅔	

About the magnitude of the Fixed stars, however, thus.

The Fixed stars of Magnitude are			times than the Great Orb.
first	greater	67	
second	greater	20	
third	greater	8	
fourth	greater	2½	
fifth	smaller	3	
sixth	smaller	25	

Thus, that is, with a correction applied to his numbers; whereas earlier he had published that stars of the first Magnitude exceed the Great Orb 20,053 times; of the second, 5935; of the third, 2506; of the fourth, 744; of the fifth, 92; of the sixth, 11½.

Further, since not only the Non-wandering stars but the Wandering ones too, through the intervention of the telescope, are disco- vered to be of a smaller diameter than they are commonly held to be, for that reason Martinus Hortensius [Maarten van den Hove], Disciple and Assistant of Lansbergen, prompted by the observation of Mercury made by us and recorded above, and by certain others besides, supposed first of all that the apparent diameters of the Wandering stars were: of Mercury, indeed, 19″; of Venus, 53″; of Mars, 36″; of Jupiter, 50″; of Saturn, 37″; and then he pronounced thus on their magnitude.

They are			times than the Earth.
Mercury	smaller	6510	
Venus	smaller	1109	
Mars	smaller	1534	
Jupiter	smaller	1¼	

They are			times than the Earth.
	Saturn	greater	2⅕

He supposed, however, that the diameters of the Non-wandering stars were: of Sirius, indeed, or the Great Dog, which is set outside the order, 10″; and of the others, of the first Magnitude, 8″; of the second, 6″; of the third, 5″; of the fourth, 4″; of the fifth, 3″; of the sixth, 2″; and then he held Sirius to be smaller than the Great Orb 3 [?]/5 times, and the other fixed stars likewise smaller, as follows:

The Fixed stars of Magnitude are	smaller than the Great Orb, times
first	6⅓
second	15
third	25 2/[?]
fourth	50
fifth	122
sixth	412

Moreover, since he also supposed that there could be assumed (as had already been assumed by Lansbergen) of the Fixed stars a parallax with respect to the Great Orb of 30″, and so that their distance of 6875 semidiameters of the Great Orb could be assumed, for that reason he deduced that Sirius in particular could be held to be smaller than the Great Orb 217 times, and the other Fixed stars similarly, in this way.

The Fixed stars of Magnitude are	smaller than the Great Orb, times
first	422
second	1012
third	1725
fourth	3385
fifth	8245
sixth	27826

But too much on this matter.

CAPVT XII.

Chapter 12.

Quale Mundi Syſtema ſit, quod Tycho Braheus induxit.

What kind of System of the World it is that Tycho Brahe introduced.

From what has already been said about the System of Copernicus, it is easy to understand the one that Tycho Brahe, a Danish nobleman and a new

Hipparchus, brought in as the last century was already declining. Here is what sort of system he proposed it to be.

Diagram. An uncaptioned woodcut of a world system, filling the upper part of the page. It carries no letters and no words; its only signs are planetary and lunar signs and a sun drawn as a face. Outermost, two concentric circles form a band in which small stars are set at intervals all round. Within the band are three large circles, each with a planetary sign standing on its line at the top, from outside inward: ♄ (Saturn), ♃ (Jupiter), ♂ (Mars, its arrow pointing right). The ♄ circle is interrupted by a short break in its line on the left side. Each of the three carries a small star-shaped mark on its line at the bottom, and a further star stands in the outer band directly above ♄. At the middle of the figure is the sun, drawn as a face with rays, and around it two small circles: the outer with ♀ (Venus) standing on its line at the top, the inner with ☿ (Mercury) on its line at the top. Each of these carries a small star-shaped mark on its line at the bottom, and a small wedge-shaped mark lies on the left of the ♀ circle. A dotted circle surrounds the sun and both small circles; its lowest point falls on a small ring with a central dot, which stands below the sun on the figure's vertical axis and is not otherwise labelled. Around that ring is a small circle with ☾ (the Moon) at its bottom. A larger solid circle, centred on the same ring, passes through the sun at its top and cuts the dotted circle and the two small circles. The three large circles appear to be centred on the sun, but this is an estimate, not a measurement.

- ♄ (top of the outermost of the three large circles): Saturn
- ♃ (top of the middle large circle): Jupiter
- ♂ (top of the innermost large circle): Mars
- ♀ (top of the outer small circle round the sun): Venus
- ☿ (top of the inner small circle round the sun): Mercury
- ☾ (bottom of the small circle round the central ring): the Moon

Namely, one may see in it, first, that the Firmament, or the Sphere of the Fixed stars, is the outermost part of the World; that the innermost part, however, or the one occupying its centre, is the Earth; and that in the interval the Planets are placed, which perform their motions there through most free, that is, most fluid spaces.

Indeed, it was Tycho most of all who shattered the solid spheres and drove them out of the aether; after he had, just as he observed comets crossing through the aethereal spaces, so also been the first to demonstrate it; and he found that Mercury and Venus are carried both beyond and on this side of the Sun; and other things of this kind. Meanwhile, however, he held that there is spread through those spaces a certain most tenuous, most pure and most flowing substance, which he also called the aethereal air [Auram ætheriam].

Next, that three particular movables [mobilia] are carried round the Earth as though round a centre: the Moon, for its part, nearest, with a monthly motion; the Sun, more remote and as it were in the middle, with an annual motion; the

firmament, or sphere of the Fixed stars, most remote, with that slowest motion of twenty-five thousand years.

In addition, that the five wandering stars perform special motions round the Sun, as though round a centre: Mercury, namely, a three-month one, Venus an eight-month one, Mars a two-year one, and so on. And this indeed on the condition that the Sun, running through the zodiac with its annual motion, carries them all round; that meanwhile Mercury and Venus themselves, with their revolutions about it, do not encompass the Earth, but that Mars, Jupiter and Saturn do encompass it with theirs; and that Mars in particular at times becomes nearer to the Earth than the Sun itself.

Finally, since you see no mention made here of the daily motion, it seems it must be understood that those same three Movables, the Moon, the Sun and the Sphere of the Fixed stars, while they are carried along the zodiac by those motions of theirs, are meanwhile rolled daily toward the west, as though of themselves; but that the five wandering stars, besides their own motions round the Sun and along the zodiac, are also carried daily toward the west — not of themselves, but drawn along by the Sun, which is for them in place of the primum mobile. It is, namely, necessary that, since the Sun holds them all bound fast to itself, as a charioteer as it were, it should carry those same stars daily round the Earth, round which it is itself led.

I said, further, that this System can very easily be understood from what has been set out about the Copernican one. For if, in place of the circle passing through the Sun, another is drawn passing through the Earth (such as the dotted one we have added), the same distance between the Sun and the Earth being kept as its semidiameter; and if either the planetary framework or the sphere of the Fixed stars is understood to be moved out for the moment in such a way that Saturn's circle is equally distant from the Fixed stars on every side; you will have entirely the System that was described earlier following Copernicus.

For the Sun will then be in the middle, or centre, of the System; Mercury and Venus will be led round it most closely, Mars, Jupiter and Saturn more remotely; but in the middle interval the Earth will be found, with the Moon led round it. So much so, accordingly, that Copernicus can be considered, not unjustly, to have gone before Tycho, and Tycho seems to have done nothing else than invert the System of Copernicus.

CAPVT XIII.

Chapter 13.

Quibus rationibus adductus illud excogitauerit.

By what reasons he was led to devise it.

And Tycho had indeed promised that he would explain and prove this System at greater length in the Work on the Restoration of Astrono- my which he had planned to work up. But even so, forestalled by death, he could not carry

the matter out; and he left in writing only that he had been moved to devise such a system as that, both because neither the Ptolemaic nor the Copernican could be tolerated, and because, according to it, all the phenomena were saved as aptly as possible.

Against the Ptolemaic, moreover, he objected, first, its inelegant arrangement of the celestial orbs; next, the superfluous assumption of so many and such large epicycles for saving the phenomena of retrogradations and stations; and further that offence against the principles of the art, that in it the uniformity of circular motion is admitted not about its own centre but about the centre of another eccentric (namely the equant). Not to add anything about the solidity of the celestial spheres, which the same man thoroughly demonstrated cannot stand with the recent observations.

Against the Copernican, however, he objected three things above all. One, that although in it the things held to be superfluous and incongruous in the Ptolemaic are very skilfully guarded against, and nothing in fact offends against the principles of mathematics, yet that absurdity against the principles of physics is admitted: that it lays down that the Earth, since it is, he says, a gross, sluggish body, unfit for moving, is driven with no slacker a course of motion (and that, too, a threefold one) than those aethereal Lights. The second, that it is accordingly opposed to Holy Scripture, which several times affirms the stability of the Earth itself. The third, that it supposes that space between the orb of Saturn and the eighth sphere to be almost immeasurable, and yet wholly empty of stars.

And finally he mentioned this point especially in his own favour: that, with all inconveniences of this kind avoided, while the Sun traverses the zodiac with its annual motion and meanwhile the five planets, accompanying it, perform their motions round it, those principal phenomena of stations and retrogradations are saved as a result, without any epicycles; and that it is explained why Mercury and Venus appear to digress so little from the Sun; why Mars, Jupiter and Saturn are at times opposed to it (the Earth, that is, being intercepted), why they then pass closest to the Earth and grow largest in appearance; why, in computing the motions of each of them, the simple motion of the Sun is always found mixed in; and the other things there are of this kind.

As for the remaining varieties of the apparent inequality, however, which the ancients saved by eccentrics and equants, and Copernicus by an epicycle on the circumference of an eccentric, he said that they too can easily be saved in his own hypothesis, either by a small circle on an orb eccentric about the Sun, or by a double small circle on some concentric orb; as he promised he would explain more fully in that Work he had in hand.

CAPVT XIV.

Chapter 14.

Qua ratione id à Tychonis Sectatoribus propugnetur.

In what way it is defended by Tycho's followers.

Further, since it is established, now in these times, that the arrangement of the planets is such that it plainly seems necessary that either the Copernican or the Tychonic System is true, there are for that reason a good many (indeed almost

all who on other grounds have turned away from Copernicus) who, having rejected the hypotheses of the ancients, follow Tycho: partly induced by the fame of his name and of the celestial observations he carried out; partly persuaded that the objections made above, from astronomy, from physics, and above all from Holy Scripture, always stand, whatever the Copernicans may reply.

And yet, because various difficulties are raised against them too, they for that reason meet those difficulties in such a way as to supply the place of the answers that Tycho would perhaps have given.

For FIRST, indeed, it is objected that it is absurd to assign to one body two motions in its own right [per ſe]: such, namely, as are attributed to the Moon, the Sun and the firmament, when they are asserted to perform particular circuits along the zodiac, or toward the east, and yet meanwhile to be carried westward by the diurnal revolution.

But some reply that a double motion does not for that reason belong to these three, or to any one of them, but that a single motion does, and that a spiral one, and directed westward. The matter is understood from what was said in the previous book about the variety of hypotheses. It need only be noted that accordingly the sphere of the fixed stars itself must be carried westward the fastest of all, and describe the most closely packed spirals, touching one another; that the Sun moves more sluggishly and describes looser spirals; and that the Moon moves the most sluggishly and describes the loosest spirals. And that from this it comes about, both that the Sun, by one degree each day, and the Moon, by thirteen, slower than the fixed stars, appear to move eastward; and that the Sun in one year, and the Moon in one month, so per-

form their excursions to the north and to the south as to complete a circuit beneath the fixed stars themselves.

Since, however, these cannot say with respect to what the firmament itself is held likewise to make excursions to the north and to the south, others for that reason reply that a primum mobile must be admitted above the firmament, which turns the firmament westward each day; and that the firmament itself meanwhile moves eastward with a motion proper to itself, along the zodiac, and, in keeping with the zodiac's obliquity, tends to the north and the south. That is, that another sphere above the firmament is necessary on other grounds, in which the dodecatemories, or immobile signs of the zodiac, are understood to reside, while the mobile signs, or asterisms, run along its circuit.

SECOND: that it is exceedingly incongruous to assign to the firmament, or even to a primum mobile existing beyond it, so great and so far removed,

a diurnal motion which is both of incredible speed and cannot be of use for carrying the spheres of the planets round, inasmuch as these are not solid at all, and therefore cannot be swept along.

But they reply that neither the firmament, nor even a further mobile, is of such vastness as Copernicus imagines; and that its motion, though extremely swift, is not to be thought incongruous, because it is congruent with the very mass of the body. And they reply that, just as that motion by which a horse covers a distance, and which would be incredibly swift with respect to an ant or a tortoise if the ant or tortoise covered the same distance in the same time, is not to be held incredibly swift with respect to the horse itself, so a swift motion ought not to be thought beyond all belief in the firmament, or in a further

sphere: a motion which, nevertheless, could be thought of this kind in a small globe.

As for what is added, however, about an impression that could not be made on the mobiles below the firmament, because of the fluidity of the intervening spaces: either that no such impression at all is necessary, if indeed the motions of the lower mobiles are held to take place along spirals; or else that an impression can be made on the very globes of the planets, even with solid spheres excluded, and through the freest spaces, just as it is admitted to be made by the Copernicans themselves, when they admit that the planets, likewise moving about in the most liquid aether, can be carried round by rays emitted from the Sun.

THIRD: that it is quite ill-fitting that that whole structure of the planets should each day be, as it were, put out of joint, both about the Earth itself, as though about a centre not its own, and beneath the sphere of the fixed stars itself, from which it is unequally distant, or with which it is not concentric.

But they reply that nothing can be ill-fitting in that work which the most wise Craftsman arranged. For, they reply, no dislocation at all takes place when the planets are carried round by the Sun about a centre not their own, as might be thought if they were pulled apart by some weight, and the greater part of the structure, on one side of the Earth, and the lesser part, on the other, could not, as it were, be balanced; nor is it admitted by everyone[3] that the circuits of the planets are eccentric with respect to the sphere of the fixed stars; since, on another count too, the structure of the planets itself revolves daily about the Earth in such a way that every part of it describes a circle concentric with the Earth.

But, they reply, it is not unusual (as can be urged besides) that the planets, while they perform particular motions about the Sun, should meanwhile be twisted aside to such an extent that, carried off by a most rapid motion, they are driven to perform those daily circuits. For both according to the Ptolemaics, they reply, the planets, while performing their own motions, are meanwhile diverted and swept away by another mobile; and according to the Copernicans the Earth itself in particular, while it is carried round by a motion proper to

[3]the Latin prints three negatives, *Neque à nemine non admitti*; rendered word for word, as the following clause requires

itself, is meanwhile drawn off and swept away by another, impressed by the Sun through the emitted rays. In the same way, too, the Moon itself, while it is carried round the Earth, is, on their account, meanwhile transferred through the zodiac by the Sun together with the Earth; and so too are the planets, or Jovial little moons, while they are carried round Jupiter itself.

LASTLY: that it is wholly improbable that that so great interval between Venus and Mars should be empty; and that, with so great a space available, Mars still cannot be drawn off far enough for its circuit not to intersect the circuit of the Sun.

But they reply that, just as the Founder of the World made the intervals of the fixed stars so unequal among themselves, so he brought it about that the spaces between the planets should be unequal. Things, that is, delight in variety, and the perfection of the world consists in it in such a way that it ought rather to seem improbable if such variety were not closely observed in the things of nature.

Further, that intersection of the Sun's circuit with the circuit of Mars is, they reply, an obstacle to nothing: both because circuits of this kind lie through the freest spaces, and are discerned by the mind only; and because never can the Sun and

Mars meet each other at those places; since Mars is not in them except while it is acronychal [Acronychus], or around its very opposition with the Sun.

And so those, indeed, defend the opinion.

CAPVT XV.

Chapter 15.

Quæ ſit iuxta ipſum Diſtantia, & Magnitudo Siderum?

What, according to him, is the distance and the magnitude of the stars?

It remains, by way of a coronis: since Tycho not only disapproved of that huge vastness of the Copernican system, but also introduced a system far narrower than the Ptolemaic, it remains, I say, that we examine what he thought not only about the distance and magnitude of the planets, but also about the distance and magnitude of the fixed stars [Siderum Affixorum].

As regards the planets, then: after he had hunted down their parallaxes as far as was possible, he pronounced the distance of each from the Earth (while they are situated around the mean longitudes) to be as follows.

Mean distance, by which they are removed from the Earth	Moon	is, in terrestrial Semidiameters	56½
Mean distance, by which they are removed from the Earth	Mercury	is, in terrestrial Semidiameters	1150
Mean distance, by which they are removed from the Earth	Venus	is, in terrestrial Semidiameters	1150

Mean distance, by which they are removed from the Earth	Sun	is, in terrestrial Semidiameters	1150
Mean distance, by which they are removed from the Earth	Mars	is, in terrestrial Semidiameters	1745
Mean distance, by which they are removed from the Earth	Jupiter	is, in terrestrial Semidiameters	3990
Mean distance, by which they are removed from the Earth	Saturn	is, in terrestrial Semidiameters	10550

And after he had observed carefully, and as precisely as he could (the telescope not yet having been invented [adiuuento] [recte: adinuento]), he defined the apparent diameters of each as follows:

Apparent diameter, at mean distance,	of the Moon	is of minutes	32
Apparent diameter, at mean distance,	of Mercury	is of minutes	2⅙
Apparent diameter, at mean distance,	of Venus	is of minutes	3¼
Apparent diameter, at mean distance,	of the Sun	is of minutes	31
Apparent diameter, at mean distance,	of Mars	is of minutes	1¾
Apparent diameter, at mean distance,	of Jupiter	is of minutes	2¾
Apparent diameter, at mean distance,	of Saturn	is of minutes	1⅚

Then he pronounced the magnitude of each, as follows:

are	the Moon	smaller	42	times than the Earth.
are	Mercury	smaller	19	times than the Earth.
are	Venus	smaller	6	times than the Earth.
are	the Sun	greater	139	times than the Earth.
are	Mars	smaller	13	times than the Earth.
are	Jupiter	greater	14	times than the Earth.
are	Saturn	greater	22	times than the Earth.

As regards the fixed stars, however: after he noted that they must be higher [euectiores] than Saturn, not only when it is at its mean distance, such as has already been recited, but also when at its greatest, which he set at 12,300 terrestrial semidiameters; and higher also than the apogee of a certain second epicycle, as it were, to which he grants a distance of 12,900 semidiameters; for that reason he says that the sphere of the fixed stars can hardly be distant from the Earth by less [propiùs] than 13,000 terrestrial semidiameters.

And since it is uncertain whether all the stars are equally distant from the Earth [à Terris], and it seems more probable that some of them are placed higher, some lower, within the compass of the same eighth sphere, we shall have acted more prudently, he says, if we add a further thousand semidiameters [?] to the former sum.

Therefore he also set the distance of the fixed stars from the Earth roughly (for these things, he says, are not to be traced out by an exact and fine measure) at 14,000 terrestrial semidiameters.

Next, however, from this distance, and from the apparent diameters of the fixed stars, defined as far as was possible (without the help of the telescope) in this manner:

The apparent diameter of fixed stars of the magnitude	first	is of minutes	2
The apparent diameter of fixed stars of the magnitude	second	is of minutes	1½
The apparent diameter of fixed stars of the magnitude	third	is of minutes	1 1/11
The apparent diameter of fixed stars of the magnitude	fourth	is of minutes	0¾
The apparent diameter of fixed stars of the magnitude	fifth	is of minutes	0½
The apparent diameter of fixed stars of the magnitude	sixth	is of minutes	0⅓

he deduced that the magnitude, or bulk, of each, according to its order, stands thus:

The fixed stars of the magnitude	first	are greater [?]	68	times than the Earth.
The fixed stars of the magnitude	second	are greater [?]	28½	times than the Earth.
The fixed stars of the magnitude	third	are greater [?]	11	times than the Earth.
The fixed stars of the magnitude	fourth	are greater [?]	3½	times than the Earth.
The fixed stars of the magnitude	fifth	are greater [?]	1 1/18	times than the Earth.
The fixed stars of the magnitude	sixth	are smaller	3	times than the Earth.

He added, however, since not all first-order

or first-magnitude stars appear equal among themselves, and the proposed magnitude properly fits the middling ones — he added, I say, that it can happen that those which are greatest in the first order, such as Canis Major and Lyra, exceed the Earth a hundred times; those which are least, forty-five times. And so, indeed, Tycho.

But concerning these systems, and concerning the whole Astronomical Instruction, thus far.

The End.

ORATIO INAVGVRALIS

Inaugural Oration

HABITA IN REGIO COLLEGIO Die Nouembris XXIII.

Delivered in the Royal College, on November 23

A PETRO GASSENDO Regio Matheseos Profeſſore.

By Pierre Gassendi, Royal Professor of Mathematics

Any who know me will be astonished that a man devoted to divine offices turns aside to human studies, and, as though he were weary of his own function, exchanges the pulpit of the Church for that of the Academy. It can, of course, seem to be this: to have enlisted in the sacred warfare and to desert to the profane; to have put one's hand to the plough and to look back; to have been set free and still to be thinking of Egypt. But truly, as far as I am concerned, I would not take the matter in hand without shame if I were indeed undertaking it of my own spontaneous and personal choice; if, not once, and again, and a third time ordered to comply, I were obeying a voice which it was permitted to interpret as divine.[4]

The voice itself, moreover, is yours, MOST EMINENT CARDINAL — you who, when about to present me to the Most Christian King, by whom I was to be appointed, deigned to address me in such a way that you broke me, though I resisted much and long, by your patience, shall I say, or by your kindness; and you who could have done so by commanding preferred, by persuading, to compel me at last to surrender. You brought me, namely, to understand that I was not being called to a profane office — one which Abraham, the Father of believers, would not have considered foreign to himself, since, as Hecataeus, Berossus and Nicolaus of Damascus testify, he taught the Egyptians the science of numbers and of the stars. And that, although Aristotle writes that the Egyptian priests themselves invented the mathematical sciences, while, after the worship rendered to the gods, they had time in abundance in which they were permitted to be at leisure, from this at least it is evident that these sciences were believed to take their origin from divine men, and that their profession was not held unbecoming to priests. And that — lest anyone think that only the heathen are to be counted in this class — see, St Basil is commended by Blessed Gregory of Nazianzus for having been versed to no ordinary degree in astrology, geometry, arithmetic and the others; and that both the other Fathers and, in particular, the Blessed Jerome and Augustine declare in many places how necessary these disciplines are for the interpretation of Sacred Scripture.

You brought me, moreover, to understand that the sacred Book by which God has willed to become known to men is twofold: the one written, and which goes by the name of the Holy Bible; the other this open face, or majesty, and Nature of things. And that, while

the theologians, men learned in supernatural knowledge, are appointed to interpret the former, the mathematicians have been fitted to interpret the latter — men who, equipped with natural knowledge, can not undeservedly be held natural theologians. That is to say, that Truth itself, which is nothing other than God, is made manifest by a twofold light — that of Revelation, namely, and that of Demonstration; and that what is called Theology uses the former,

[4]The negation in the second condition, "si non ſemel, ac iterùm, tertiúmque iuſſus obſequi, obtemperarem voci", can be taken with "ſemel" ("not once only, but again and a third time ordered") or with "obtemperarem" ("if, ordered once, again and a third time, I did not obey"); the order of the Latin is kept here.

and mathematics [Matheſin] alone the latter; since of the other sciences, as they are called, there are indeed not demonstrations but conjectures, unless they enjoy some light of mathematics.

Finally, you brought me to understand that the Temple in which God requires initiates [Myſtas], or priests, is twofold: the one, namely, the Church itself, in which He is adored according to the revelation of the Divine Word; the other, this System of things, in which, recognised according to the marks of an ineffable wisdom, He is worshipped. For this reason you wished me, too, merely to be transferred from Temple to Temple: because, since there are divisions of graces, and in the house of God there are many mansions, you believed it would come about that my industry, such as it is, could be placed not unprofitably in this part of the Divine household.

This, then, is your voice, by which — constantly called, like another Samuel (if one may say so) — I composed my mind to obey, reckoning that you hold so eminent a place in the Church, and that you dispense the offices over which you have been set, as Chief of the Sacred Offices [Maximus à ſacris] to the Most Christian King, with such foresight, that it shamed me to resist any longer, and not to take up that post in which you wished me placed and adorn, as far as my strength allowed, that Sparta which you were prescribing.[5]

Moreover, since I well remembered that heroic virtue and consummate piety, in which, as it was given to know you thoroughly, you shone forth right from the Hermitage [Eremo] and your first mitres, I easily brought myself to think that whatever counsel you adopted could not fail to proceed from the highest virtue and piety.

Accordingly I now present myself to you, and to the whole most illustrious and most noble assembly, in order to undertake under such great auspices the work which you ordered me to carry out; and, being about to give lectures on cosmography, or on the World, to begin with a hymn to the Founder of the World. For since Plato, who was held divine among the philosophers, gave that celebrated answer to one asking what God was doing — [Greek: Γεωμετρεῖν τὸν Θε[?]ν (geōmetrein ton The[?]n, "that God practises geometry")], *that God practises geometry* — I seem able to do nothing either more suited to my subject, or more in keeping with my kind of life, or more worthy of your attention and that of the whole most celebrated assembly, than if, when I too, playing the part of a Christian philosopher, shall answer no differently than he, I strive to say how I think God practises geometry.

Now in the first place, since geometry is practised either by contemplating or by acting (on which basis they distinguish theorems and problems), it can seem that God is, not unfittingly, understood to practise geometry both while He

[5] "vt reſiſtere diutiùs puduerit; neque eam adire ſtationem, … ac pro viribus eam Spartam, quam præſcribereſ, exornare" can be taken as "I was ashamed to resist any longer, and ashamed not to take up that post and adorn that Sparta", or, with "puduerit" understood again after "neque", as "I was ashamed to resist any longer, and not ashamed to take up that post and to adorn that Sparta"; the order of the Latin is kept here.

contemplates, and above all considers Himself, and while He acts, but most of all creates and governs the World. And indeed, to speak first of contemplation, it must certainly be supposed that this is the difference between the divine and the human: that the human advances by reasoning, or by proceeding step by step from principles to conclusions; the divine, to which

all things are naked and open; to which no consequent is less manifest than the antecedent; to which every proposition is a common notion [communis ſententia], or axiom — the divine, I say, is accomplished by a simple understanding, and one without any succession.

Now, while God attends to Himself, does He look upon anything such that He may be judged to contemplate something geometrically? Evidently: first His own Nature, and then the sacred Triad of Hypostases [Hypoſtaſeon], or Persons. For in the first place He indeed beholds the Nature, and holds it as a Sphere whose centre (as even a heathen defines it) is everywhere, its circumference nowhere. At this point it is fitting to give a reminder: that, since no one has ever seen God, and since God, dwelling in light inaccessible and dazzling with His brightness the eyes of men, as though of owls, is said to have made darkness His hiding place, there is for that reason no cause why we — since we are wretched little mannikins, and dust and ashes — should strive, I do not say to declare, but not even to guess, anything about so great a Majesty as it is in itself. That, accordingly, it is becoming for us to hold ourselves thus: that God knows our frame [figmentum], and with a certain fatherly indulgence bears with us when we speak of Him, not as He is in Himself, but as is suited to our capacity; and that it is abundantly enough if we stammer those things out of which He Himself, inasmuch as He is good, may perfect praise, as out of the mouth of infants and sucklings.

We therefore conceive that God, while He contemplates His own nature, holds it as though it were a Sphere: inasmuch as no figure is understood by us to be more capacious, more uniform, more perfect; inasmuch as, since it is supremely indivi-

sible, it is itself, as it were, the centre from which the divine perfections — which they also name properties and attributes — flow out like certain rays; inasmuch as these perfections are to it, as it were, the circumference by which it is, as it were, circumscribed, or, in such way as it can be defined, is distinguished from every thing that is not God. Although, lest we should on that account imagine some true limitation, we say that a Circumference of this kind exists nowhere, signifying that none of the divine perfections is outermost; none in which there is anything outermost. In the same way, lest the word Centre too should suggest something limited, we for that reason say that it is everywhere, signifying that the divine nature is the same in all, and with all, the perfections; inasmuch as it is at once an inexhaustible fountain and a boundless Ocean.

And indeed it is fitting to marvel at a Centre of such fruitfulness that, though it is a point, it is nevertheless held to be immense: but that, to be sure, is the same as the Monad [Monas], or unity — the name by which Pythagoras long

ago designated God. There is a celebrated saying of Trismegistus: "The Monad begot a Monad, and reflected its own ardour upon itself." On the one hand, some take this of the most holy mystery of the Trinity; on the other, Thomas Aquinas judges that it ought rather to be interpreted so that God, who is one, is understood to have founded the World, which is also one, for love of Himself. But perhaps the matter may point to this: that, whereas numbers multiplied into themselves beget other numbers than themselves — for two taken twice creates four, three taken three times nine, four taken four times sixteen — yet the Monad, or unity, brings forth nothing other,

than a Monad, or unity; since one taken once is only one. And whereas two, three and the other numbers, by a manifold leading of themselves into themselves, and leading back, spread themselves out, as it were, into squares, cubes, square-squares, square-cubes, cube-cubes, and other greater and greater numbers, as into certain rays: the Monad itself, or unity, perpetually returning into itself, and being to itself root, and square, and cube, and the rest, reflects its very rays, or (by another name) its very ardour, back into itself.

On this account, then, God is truly a Monad, inasmuch as in predicating He cannot be led into any attribute of His that God is not, or that declares of God anything other than God. For when someone says, "God is good", he says nothing other than "God is God": that God is His own goodness; and that neither this attribute, nor Wisdom, nor the rest, are anything other than God Himself.[6] Hence the Monad can also be said to be predicated of the Monad, and to reflect its own ardour upon itself; inasmuch as the divine nature, in predicating, refers any attribute whatever to itself, and shares its own denomination with it. And again, to be the same as the Centre that is everywhere; inasmuch as there is no attribute in which, and with which, it is not the same, and which it does not, as it were, reflect into itself — like something luminous placed at the centre of a Sphere, while the rays, as they go out, so return into the centre.

From this, moreover, is understood not only the divine Unity — in that it is as repugnant for the Divine nature to be multiplied as for either a Monad or the centre of a sphere — but also the Simplicity, in that as alien to God is

every composition of attributes that are not God, as every texture of squares and cubes that are not unity is to Unity. And since, on other grounds, He is a Sphere whose centre is everywhere, whose circumference is without an extreme, He is also understood to be, as Infinite in perfection, so Immense in space, Eternal in duration. Indeed, He is also understood, as Immutable — in that there is no perfection which He could acquire, none which He could lose — so also Immovable, in that there is no place to which He could approach, or from which He could withdraw; and Unbegotten and Immortal, in that He is

[6] "quòd Deus ſit bonitas ſua; neque … ſint" may be taken as setting out what the speaker says ("that God is His own goodness") or as giving the reason for it ("because God is His own goodness"); the first is followed here.

incapable of beginning and of ceasing, as, namely, [Greek: τὸ [?]ν (to on, "that which is")], *that very thing which is*.

I would turn out more long-winded than is fair if I wished to review the rest, or to show also in them what geometrical ratios God contemplates. For concerning Power — to speak by way of example — understanding the relation that holds between moving force and weight, He compares all creatable things, resting, as it were, in their own nothingness, with that omnipotence of His which alone is equal to moving them out of nothing. Concerning Justice: perceiving the ratios both of similarity and of equality, He recognises the former in that species of justice which they call Distributive, inasmuch as it assigns to each according to their own [?] works; and the latter in that one, the Commutative, inasmuch as, although no one can first give what may be repaid to him, He Himself is nevertheless so good that He crowns the gifts which He bestows.[7] Concerning Goodness, then, and indeed concerning Clemency and Mercy: attending to the ratios both of greater and of lesser inequality, He sees through how, according to the former, He may reward beyond

what they deserve, the upright; and how, according to the latter, He may punish the wicked short of what they deserve. Concerning Knowledge, and therefore concerning Wisdom and Providence: reaching mightily from end to end, He understands — just as among congruent and incongruent figures — whatever is either consonant or dissonant in all things, so that from this there is the ratio by which He disposes all things sweetly. Finally, concerning Predestination: considering the height of the riches of knowledge and wisdom, and knowing thoroughly what is the length, what the breadth, what the depth, or what the abyss, of the eternal judgements and decrees, He beholds the commensuration that exists between the mass of men, and their works, whether good or bad, with His own good pleasure; even though He has made the judgements incomprehensible to us, and the ways not to be traced, so that there is something for us to wonder at rather than to search out — as if these were, for us, incommensurable and, as it were, irrational, or surd, and inexpressible quantities, as the geometers call them.

Now, as regards the sacred Triad of Hypostases, or Persons: the Triad itself, truly, seems to be that on account of which God can be said, in contemplating, ἀεὶ γεωμετρεῖν [Greek: aei geōmetrein, "always to practise geometry"]: *to exercise a certain eternal* — and indeed super-eminent, super-excellent, not to be compared with any — *geometry*, in keeping with that: "My Father works even until now, and I work." That is to say, by the very act of contemplating, two Hypostases, or Persons, come into existence: the one of Him who understands, or of the eternal Father; the other of the Word, or of the eternal Son. And it is as if this Contemplation, by which the Father and the Son, once constituted,

[7] "illi" in "quod illi retribuatur" may refer to God ("repaid to Him") or to the giver ("repaid to him"); the context favours the giver, though the grammar does not exclude God, and the lower case is kept.

behold each other mutually, were, in the most eminent manner, at once the Proposition and the Assumption of an incomparable Syllogis-

m; an ardour cannot fail to follow — or rather, a reciprocal Love cannot fail to be kindled at the same time, or to coexist: namely, the third Hypostasis, or Person, of the Holy Spirit, which, after the manner of some Conclusion, closes the number of the productions and of the eternal Persons.

Shall we therefore again regard this mystery of the Trinity, which is to be adored, as a Sphere, whose Centre, as it were, is the eternal Father, who is fittingly called the fount, origin and principle of the whole Divinity; whose Circumference is the Son, in whom, we read, the fullness of the Divinity dwells; and whose Radii, coming between the centre and the circumference, are the Holy Spirit, who is the common, and as it were intervening, ardour of the Father and of the Son, and as it were the mutual link or bond? Or must it rather be said that whatever sublime and magnificent thing human geometry still seeks stands out pre-eminently in this Mystery? It is very well known that what they call the Quadrature of the circle still lies hidden; and that the matter therefore comes down to describing a Triangle such that, if it should show the Triangle's base to be equal to the circumference of the circle, it would then at last demonstrate that the Triangle is equal to the Circle. But in this most august Mystery the most glorious Triad of persons is equated with the infinite essence, and with its fecundity, as with a Circle — or, so to speak, and indeed more truly, is wholly identified with it — in such a way that, since there is one and the same essence of all and of each, there is accordingly one and the same immensity, eternity, and fullness of perfections.

So, while human geometry does not yet know how to trisect an angle, or to divide it and, without an accommoda-

tion — a mechanical one — to show it divided into three equal parts, we have in this Mystery one Essence, not so much trisected as communicated whole to three equal Supposita, which, although they possess it whole and undivided, both together and severally, are nevertheless really distinct from one another. And while geometry still marvels that in those Angles which are made at the contact of a circle there is something greater, there is something less, there is not an equal; or that it is possible to pass from the lesser to the greater, from the greater to the lesser, and yet never through the equal: behold, in these divine Supposita, or Hypostases, identified with the Essence itself, there is indeed a producer, and there is also a product (between which there is usually held commonly to be a relation of Disquiparance [Diſquiparantiæ relatio]), and yet there is no greater, no less, but there is sheer equality; since neither is the producing Person a cause, so as to be greater on that account, nor does the Person produced arise in such a way as to depend as if it were an effect, and so be capable of being judged less.

Moreover, geometry still knows no construction [deſcriptionem] other than a mechanical one of two lines that are mean proportionals between two given lines, such that the solid made upon the second, similar to the solid made upon

the first, has to it the ratio of the extremes. Namely, from this thing's being unknown, it is known that how a cube is to be doubled is not known; and that, for this reason, error was committed when, at the command of Minos [Minoë], the tomb of Glaucus, and at the command of Apollo, the altar of the Delians, had to be doubled; just as Chares also erred in the opposite direction when, having undertaken to double the Rhodian Colossus in every dimension, he asked for only double the material. But here, in a wonderful way, between God,

and Man, as between extremes, there is One who is constituted of two Natures, and on whom the name of Mediator has been bestowed — Θεάνθρωπος [Greek: Theanthrōpos, "God-man"], Christ: a wonderful Composite, namely, which is, as it were, founded in the second Hypostasis, or person, of the Word (human nature having been assumed into it); and which therefore, compared with either Nature, and reconciling the lowest with the highest (as is sung in the Church), has the ratio of the extremes. And indeed, while geometry commonly commends its Hyperbola for the construction of τῶν ἀσυμπτώτων [Greek: tōn asymptōtōn, "the asymptotes"], *lines that do not meet*, even though, produced to infinity, they continually approach each other: here there is a kind of Hyperbola greater than every hyperbole, inasmuch as in it, rather, those things which are infinitely distant are joined.

Moreover, while geometry prides itself on that Problem by which, Two figures being given, a third is constructed which is equal to the one and similar to the other (Plutarch, indeed, reckons that it was rather this on account of which Pythagoras offered sacrifice, than that celebrated Theorem about the Square on the subtending side being equal to the squares on the sides that enclose the right angle), that is what is wonderful here: that, with God on the one side and Man on the other being given — if only one may say so — there is constituted, as it were a third thing, the very same God-man [Θεάνθρωπος], or Mediator of God and men, Christ, who, according to the Creed, is equal to the Father according to the divinity; and, according to the nature assumed, is, according to the Apostle, made in the likeness of men, and found in bearing as a Man. But enough of this concerning the former, or Contemplative, part.

To the latter, or Active, part — namely, with respect to

this World, or universe of things, insofar as God is its Author and Governor — as far as that is concerned, it is plainly evident that not only Philosophy but the Sacred oracles too declare γεωμετρεῖν τὸν θεὸν [Greek: geōmetrein ton theon, "that God practises geometry"], *that God practises Geometry*; for the words in which [He] is said to make all things in Number, Weight and Measure mean nothing else. And since God — even on the authority of Plato himself — governs the World in no other way than He founded it (from which it follows that the conservation of the World and of things is understood to be nothing other than a kind of continuous production), it is therefore enough that we touch on a few points about this divine Geometry itself: both concerning the origin of the World and of its principal parts, which endure constantly the

same, and concerning the established series of things continually arising one after another.

Now first of all, since God held beforehand the eternal Idea of the World, then, just as He Himself, as we said earlier, was an intelligible Sphere, so He conceived the idea of a corporeal Sphere, than which no figure could be more beautiful, and then expressed it in the work:

> — You draw all things From the supernal Exemplar; most beautiful
> Yourself, Bearing the beautiful World in mind, and forming it
> After a like image.

"For what is more beautiful," he says, "than that figure which alone encloses and contains all other figures, and which can have nothing rough, nothing offensive — nothing cut into by angles, nothing by windings, nothing projecting, nothing hollowed?" Certainly, although Geometrical figures, with that perfection of evenness, indivisibi-

lity and the like, by which they are also commonly accustomed to be defined, are found only in the divine Ideas (and accordingly God alone, attending to them, may be held to act the part of the most perfect Geometer), and neither can our mind attain such figures nor our hand exhibit them (so that for this reason Plato used to complain that the good of Geometry is impaired when they are brought down from the intelligible [intelligibi] [recte: intelligibili] state to the sensible) — nevertheless, the works that come immediately from the hand of God cannot fail to reproduce most perfectly the perfection of their Exemplar. Hence that same man declared that God gave the World a figure both becoming and suited to it[8] (since it was fitting that the animal which was to contain all animals should be of that figure which would take in all figures), and that the World was therefore made globular, so that its extremity would be reached by equal radii from the centre.

And indeed it could be noted, as some do note, that Plato had in view the Problem already mentioned when, given a Matter most disordered and an Idea most beautiful, he taught that the World had been made by God, as by a most excellent Geometer, equal to the Matter and similar to the Idea. But what is displeasing is that he made Matter coeternal with God, if he meant it indeed to precede the World in duration, as most understand him; or else made the World itself coeternal as well, if [he meant it] to have preceded only by nature, as the more celebrated Interpreters take it.

For each of these conflicts with the sacred Book of Genesis, according to which it is better to observe the six-day number [Senarium dierum numerum], in which God willed the World to be founded. For not only this number

is suited to designating the perfection of the World, inasmuch as it is the first of all perfect numbers — consisting, that is, exactly of its aliquot parts, which are one, two and three — but it also excels in what Plato contends: namely, that it represents the Idea by unity, Matter by the dyad, and by the triad the Solid

[8] the reflexive "ſibi" can refer either to the World or to God, the subject of "dediſſe"

itself, or the body of the World; which Philo too holds in part. To say nothing of the fact that, from another quarter, the number six, although multiplied into itself and led back again it grows into numbers, nevertheless always returns into itself (since six times six are thirty-six; and this number six times, two hundred and sixteen; and this again six times, one thousand two hundred and ninety-six; and so on) — so that we may understand that the World is indeed both composite in act and manifold in potency, but nevertheless in reality both is unique and emulates, as far as it can, the very simplicity and unity of its Exemplar and Author.

But, since Geometry recognises no more than five bodies called Regular, did God assign their forms to the five Simple bodies of the World — the Cubic, that is, to Earth, the Icosahedral to Water, the Octahedral to Air, the Pyramidal to Fire, the Dodecahedral to Heaven? So indeed [did] Plato himself, imitating the Pythagoreans. However it may be agreed that this is to be taken — not, certainly, of the total and external figure; but either of Properties symbolically signified — for example solidity, fluidity, mobility and the rest — as the common opinion is; or of the Harmonic intervals of the planetary regions, as there are those who maintain; or, without circumlocution, of the figures of the Atoms, or of corpuscles imperceptible διὰ σμικρότητα [Greek: dia smikrotēta, "on account of smallness"], *on account of smallness*,

from which God wove together each one of the primary bodies, as he hints, not obscurely, in the *Timaeus*, and as some — among them Simplicius and Georgios Pachymeres — interpret it. But however that may be, and whatever are held to be the principal bodies of the World, it is certainly agreed that nothing more regular than they can be formed.

For even though that Soul of the World is not admitted — which, compounded ἐκ ταυτοῦ, καὶ ἑτέρου [Greek: ek tautou, kai heterou, "of the Same and of the Other"], *of the Same and the Different*, and made as it were a third Nature, contains within itself the ratios of harmonic numbers, and to which, indeed, that much-celebrated Quaternion is fitted, the Sacrament of Pythagoras and ἀεννάου φύσεως παγὰ [Greek: aennaou physeōs paga, "fount of ever-flowing nature"], *fount of everlasting nature*, on account of the number ten (and that, indeed, the number of the Principles), which its parts joined together make up; and on account of the principal species of Consonance, whose proportions it embraces within its compass (since four to two, and two to one, is the double proportion, of which the Diapason, or the so-called Octave, consists; three to two, the sesquialteral, of which the Diapente, or Fifth; four to three, the sesquitertian, of which the Diatessaron, or Fourth) — nevertheless it is evident that the nature of the bodies of the World is such that, whether you consider their mass, in which they are greatest; or their texture, in which most entire; or their cohesion, in which most congruent; or their configuration, in which most beautiful; or their position, in which most seemly; or their mutual relation, in which most ordered; or their motion or rest, in which most durable; or their

end and destination, in which most apt; or, finally, anything else whatever — nothing could be more harmonious.

Hence there is also no need, in order to explain the nature τοῦ ταυτοῦ, καὶ [?]τέρου [Greek: tou tautou, kai [?]terou — glossed by the page's own Latin that follows] — *of the Same and of the Different, or of the Undivided and the Divided with respect to bodies* — to set up geometrical progressions up to the first two Cubes, namely eight and twenty-seven. From these the number Thirty-five is put together, and it is called Harmony because it is also composed, in another way, of six, eight, nine and twelve; and in these there also consist the harmonic proportions already enumerated, and in addition the sesquioctaval, which is proper to the so-called major Tone. Nor, likewise, is there need to imagine that God made a nature mixed from both, as it were the letter *Iota*: from this letter, bisected lengthwise, its parts bound back together in the middle and drawn apart into the shape of the letter *Xi*, and bent round into a circle in opposite directions, the twofold revolutions of the heavens are understood — namely both the one of the primum mobile, or Sphere of the non-wandering stars, towards the setting, on account of the undivided nature of the Same; and that of the seven Planets themselves towards the rising, on account of the nature of the Different, divided and subdivided sevenfold. It is enough that an occasion has been made for noting that concord [concentum], or that sound so great and so sweet, on account of which their own Sirens, or Muses, were assigned to the individual Spheres — or those separate Substances, called Intelligences by the Later [writers] for this reason: that although otherwise devoid of bodily mass, they are most intelligent in the harmonic proportions prescribed [præcriptarum] [recte: præſcriptarum] by God, the true Musagetes, and as it were Apollo. Namely, as though they were the morning Stars, by whom God testifies that he is praised, and presently asks: "Who will declare the order [rationem] of the heavens, and who will make the Concert of heaven sleep?"

And that indeed — not to mention that God, again, is read to have poised the mass of the Earth with three fingers, and to have weighed the mountains in a weight and the hills in a balance; that he weighed out the Waters by measure, laid down a law for the rains, made a weight for the winds, and similar things of that kind — from which it is by no means surprising that such a symmetry and temperament is commonly recognized in the Elements that from them, although they are contrary in various ways, both in the altering and in the moving qualities, there nevertheless results a harmonic System, as though from certain high and low sounds. Excellently, to be sure, that one [says]:

> You bind the Elements by numbers, so that cold things agree with
> flames, Dry things with liquid; lest a purer Fire Fly off, or weights
> drag down the sunken Earths.

To speak now of Mixed bodies, which belong to the series of things that arise in succession, or of things generable and corruptible: is there anyone who, even among those that are usually judged imperfectly mixed, would

not admire that Bow which God openly undertook that he would set in the clouds — as though there were no other Geometer who would describe it so perfect with any compass, and, with a painter employed, adorn it with such variety, mixture, sweetness, vividness and beauty of colours? "Look upon the Bow," says the Wise man, "and bless him who made it: it is very beautiful in its splendour; the hands of the Most High have opened it out." Is there anyone, therefore, who would not look up in wonder at the Halo, or the so-called Crown, which, as it is smaller than the Rainbow [Iris] by half in diameter, so is twice as complete in circumference? Is there anyone who would not [look up in wonder at] the Parhelia, or spurious Suns, which, just as they are — of Rainbows and of Crowns intersecting one another — as it were the knots, so always keep a distance from the true Sun that is measured out and fixed? God commands the Snow to come down upon the earth, and gives it like wool. But do you suppose that those tufts of down, as it were, or snowy flocks, lack a certain divine Geometry? Behold, they themselves are nothing other than certain textures of white starlets, each of which is put together most skilfully from six rays; and these rays now indeed simple, but now branched, as it were, here and there. Do you suppose that the Salts too, which God put into the Earth for its fertility, lack [it]? Behold, the common or Marine [salt], which is commonly had only ground down, is formed constantly into the hexahedral, or cube, shape; the aluminous into the octahedral; and each of the rest into its own — however much, to those who do not turn their mind and eyes to these things, all things may appear shaped at random rather than Geometrically, and it may not at once become manifest how truly it has been said both that Nature at single moments lacks faith and that all the works of Nature are works of an Intelligence.[9]

But why should I mention Stones, among which the Emerald is born in a dodecahedral form, the Diamond in an octahedral, the Amethyst in a hexahedral, and Crystal too, not only where it is a parallelepiped, but also where it comes together into a point? So too among us the Rhomboites is produced; and everywhere the Pyrites is tessellated, the Specular [stone] laminated, and the Focarius tabular; and Whetstones [Cotes], too, keep this special feature, that besides their shape they are double in length to breadth. I would speak of the Starred, the Striated and the Horned [stones], of the Conchites, Ostreites, Pectinites and Stromboites, and of the rest; nay, even of the fluviati- le [stones] and others met with everywhere; also of Rocks and Crags, which, if time allowed, I would explain in detail also have their own native shapes. But nevertheless, in place of all, let the Lodestone [Magnes] alone stand — which, although it is otherwise

> Discoloured, dark, cheap; not it, adorning the combed tresses Of
> Kings, nor a Maiden's white Neck: ————————

[9]The construal of "fide carere momentis fingulis Naturam" is uncertain; it is rendered word for word. The first letter of "fide" is an f.

yet if anyone attends in it not only to that power of drawing iron and of turning towards the poles, but also to its emulation of the Geometrical structure of the World — since it is not only, as it is now usually called, μικρογὴ [Greek: mikrogē, glossed by the page's own Latin that follows] *Terrella*, but also μικρόκοσμος [Greek: mikrokosmos, "little world"] *Mundulus*, inasmuch as it has its own Axis, its own Centre, its own Poles, its own Equator, its own Parallels, its own Meridians, and other wonders —

> Then it surpasses fine adornments, and whatever on the Eastern
> Shores the Indian searches for in the red seaweed.

As regards Vegetable things [Vegetabilia], the Seminal power is indeed Geometrical, which God impressed in the beginning, when he commanded the Earth to bring forth the green herb, and yielding seed, and the fruit-bearing tree yielding fruit after its kind, whose seed was to be in itself. For a General cannot arrange the soldiers, and draw up the ranks and the battle line, more Geometrically and more skilfully than this power distributes all the parts of the plant, and their functions, as though certain allotted tasks. Hence, namely, those shapes of plants are distinct, as in their wholes, so in their parts; and distinct too, and fixed, are the orders and numbers by which they sprout into stalks, split into branches, spread into leaves, luxuriate into flowers, grow out into fruits: and indeed with such elegance that — as with the turbinate, the orbiculate, the angular, the cylindrical; as with the umbellate, the racemose, the spicate, the crested; as with the galeate, the umbilicate, the lunulate, the campanulate; as with the crisped, the prickly, the denticulate, the laciniate; as with the three-leaved, the five-leaved, the seven-leaved, the hundred-leaved; as with the single-rowed, the two-rowed, the four-rowed, the six-rowed; and countless others of that kind — nothing more elegant could be devised. Not to mention the proportion by which each one is tempered, so that it comes forth glad in its own soil and sky; so that, if it is weaker for some other reason, it is either strengthened with little joints; or with tendrils, as though with hands, it seizes supports; or with little hooks it clings to any thing whatever that it has touched; so that, while the offspring [fœtus] are more tender, it fortifies them with pulps, rinds, pods, little bladders, little cups, husks; indeed even with thorns, awns, and other things of that kind most becomingly shaped.

Further, in Animals themselves too, and in their Seminal power, there is a Geometry still more splendid, established then, when God commanded the Waters to bring forth great Whales [Cete grandia], and every living and moving soul according to their species, and every flying thing according to its kind: the Earth to bring forth the living soul in its kind, cattle, and creeping things, and beasts of the earth according to their species: and Man himself, whom he had formed from the slime of the earth, to grow, to multiply, and to fill the earth. Indeed that power is of such skill that our whole Mechanics [Mechanice] is to be held of no account at all, if it is compared with that which one may observe even in the structure of the smallest little animal. Truly indeed that holy man

"Your hands made me, and fashioned me; with skin and flesh you clothed me; with bones and sinews you knit me together." For what other Daedalus, or Archytas, would have been able to devise and work out such splendid Automata, and so many contrivances in them — not, indeed, for few and momentary movements, but for innumerable and constant ones, as much natural as spontaneous? And these very things indeed, above all, [are] so exquisitely wrought, so elegantly arranged, so aptly cohering, so fittingly distinguished, so unconfusedly coupled, so suitably established, so easily used, so readily obedient, that no one, attending either to a single heart, or to a single eye, or to a single hand, or to any other part whatever, and to its inimitable texture, would not be astounded and exclaim with the Psalmist, "How wonderful your knowledge has been made from me, O God!"[10] But why should he exclaim that it has been made wonderful only from himself? What, moreover, from the Elephants themselves, and the Whales? — when even the Flea, even the Mite [Acari], consists of so many and such admirable little organs and little machines that that Divine Artificer is rightly said by the holy Doctor to be so great in great things that he is not lesser in small ones.

But indeed, since the body itself is built with such great symmetry, what, pray, shall we say of the Soul, for whose sake it is prepared? May one not wonder, even in the Brutes themselves, at the order in which the animal Faculties stand to one another, while the sensing [faculty] warns, the imagining apprehends, the appetitive commands, the moving carries out? May one not wonder at the proportion by which the individual Faculties with their objects are so tempered together and commensurated that, in the relation of the patient to the agent, or of the receiver to the received, no equalization could be more exquisite and more commendable; and indeed most of all according as, from the application of the object to the faculty, sensation and pleasure follow? May one not wonder, above the rest, at that Imaginative power, so much a rival of Reason that, lest the Brutes seem too similar to us, we think it better if we say that they are driven not by reason but by Instinct, or the blind impulse of nature? For however that may be, how great, I ask, must that Geometer be, from whom the Bees have the instinct to shape their combs so skilfully with a hexahedric figure, than which there is no other more fit for leaving nothing of void, where they join at the sides and apexes? From whom does the Spider have it that, when about to weave its web into a circle, it makes provision from the centre, and draws out the rays and fastens them, between which it then lays the warp and completes the work [Greek: word not fully read [?]], or with a spiral course? From whom the Ant, that it marks out those underground hollows of its own with such great foresight, and, like an aedile, apportions its little cells according to the variety of uses? From whom the Swallow, that it moulds a semicircular nest against a beam — a form than which, if the place and the purpose are regarded, [a form] could be neither more capacious nor more

[10] "nemo … non obſtupeſcat, exclametque": printed with one "non"; read affirmatively, everyone attending to these parts is astounded and exclaims.

convenient? From whom the flock of Cranes, that in flying it arranges itself into a triangle and, with the force of the winds opposing, sends its point ahead, piercing through? From whom the shoal of Tunnies, that in that migration of theirs which is made every year through the Mediterranean, it forms itself into a cube, so as to swim always not only in a flock but also into every diversity of position; and six hundred other things of that kind?

But finally, from the Rational [soul], or the Soul of man, which God made specially to his own image and likeness, one may indeed understand how great God's Geometry is, since the soul itself consists wholly of reasons [rationibus] as it were Geometrical. For, first, by its own nature it is fitted for knowing; but knowledge does not enter into it, nor is it accommodated to it, except under the Syllogistic and Demonstrative form and figure, such as one may find only in Geometrical reasonings — or if there are any others which in some measure partake of them, or emulate their structure, and force, and perfection; as that man also prescribes concerning the things the Orator must use, who is rightly held the best master of all in the art of speaking. Hence certainly, on account of the natural commensuration, as it were, that exists between knowledge and the knower, there seem to arise those most humane and most ineffable pleasures of all, by which not only Pythagoras, Archimedes, and as many as discover something outstanding in Geometrical matters are affected — and therefore either sacrifice, or exclaim and repeat over and over that famous "eureka" [Greek: "I have found it"] — but also the Beginners themselves, who leap up with I know not what wonderful sweetness whenever they first perceive the demonstration of some Theorem.

Then, since the human Mind pours forth from itself, as though a fertile field, so great a crop of admirable Theorems, is it not fitting that it is so constituted that it contains their seeds within itself, and as it were consists of them, and is of a nature so Geometrical — since, even though it often brings forth trifles, those are nevertheless as it were spurious offspring, and dross of a sort, as it were; it itself existing of itself so fitted that it brings forth truth, and, by knowing its own Author, who is Truth, reports [it] for this reason, because he who planted the ear, as the Psalmist sings, is not able not to hear, and he who formed the eye is not able not to consider.[11] And indeed this is urged even from this: that the Soul, made to the image of God, is never able to be sated by knowing until it sees him himself, who sees all things, face to face; and, an equalization having been made between the seed of grace and the light of glory, possesses him according to every, as it were, dimension of itself; and, happy in the fullest and most secure enjoyment of him, comes to rest.

And thus far, indeed, let the Hymn be — not such as it was fitting, in keeping with the majesty of the subject, but such as it was allowed, in keeping with the slenderness of [my] powers, to sing before the most wise, most powerful, and best Author of things. Now, since the work itself must be carried out in

[11] "non audire … non conſiderare non poſſit": each infinitive carries its own "non" beside the shared "non poſſit"; read affirmatively, he cannot fail to hear and cannot fail to consider.

this most celebrated theatre of the whole — not only of the French Realm, but also of the Christian world — what, do you think, is my state of mind, MOST EMINENT CARDINAL, as I reflect that I am not able to sustain that part [perſonam] which would answer to your opinion of me, and perhaps also to the expectation of others? As I reflect that I am unequal, as one who should advance the renown of so great an Academy — renown acquired both by those luminaries Orontius, Pena, Bressius, and other distinguished predecessors, and by the most distinguished colleague Morin, to whom the Famous problem gave birth to fame, and the science of Longitudes spread [it] far and wide? As I reflect that [I am] undeserving, as one who should be co-opted into a Society of so many other celebrated Professors, so illustrious?

For Duuallius indeed, most deserving, Dean no more by age than by his own virtue, or acting in the Dean's stead, is of such a kind that, of how much he is capable in Greek and Latin Philosophy, even Aristotle himself is abundantly able to be witness — who, so often illustrated by him in Greek and in Latin, pours back upon him most abundantly the light that he receives from him. Meanwhile no one doubts that Capreolus, designated as colleague to him, is most worthy of your choice, he who has so often, with such great attendance, and with such great celebrity of name, run the Philosophical course. And the same must also be said of Aluernus, whom you likewise designated as colleague to the excellent Flauinius. To Flauinius, I say, that excellent man, who, equal to the other Doctors of the Sacred Faculty, has this special [distinction]: that he draws from the source itself, namely the Hebrew text, from which he overflows as though in a living flood. No differently Dartisius, who, in the Law that he professes, can be held to be as it were the book of Polycletus entitled the Canon, from which formerly, as from a law, the lineaments of the art were sought, as Pliny the Elder puts it.

Now in the Medical Faculty there is that Riolanus whom foreigners admire equally with natives; so that, as he examines most scrupulously all the minutest things of which the human body consists, no one seems to obey better that oracle γνῶθι σαυτὸν [Greek: gnōthi sauton, glossed by the page's own Latin that follows], *noſce teipſum*, "know yourself." There is Charterius: how much the whole nation of Physicians will be indebted to him, that great Syntagma of the Hippocratic and Galenic works proclaims, which he has most generously undertaken; and that, too, with Cusinotus substituted in the meantime, who has shown himself worthy, as of the Royal chair, so of the first rank of the August chamber. There is Moreus, whom you would not know whether he possesses more books in [his] Mind or in [his] Study: worthy to live, he through whom so many noble Physicians live; worthy to be in health [valeat], he by whom so many teachings of health [have been] illustrated. There is Akakias, who shows himself such that he can shortly outshine [his] illustrious Forebears in virtue.

But in the very Art of speaking, or Latin Eloquence, it is not nobody who knows how much they are worth:[12] both Tarinus, whom on other grounds Greek — nay, all-embracing — learning so greatly commends; and Remius, in whom the Virgilian majesty of Heroic poems contends with Tullian eloquence — a majesty long since thoroughly known to You, I am well aware. In Foreign languages, moreover, and besides Hebrew, of which it has already been spoken, no one is unaware that Mon-morius and Dubosius are men of such a kind that, powerful with a Simonidean memory, they could restore whatever there is of Greek letters, should they perish. No one [is unaware] that Sionita, who ought to have been named among the first, is of such a kind that he could teach the Arabs themselves Arabism.

As I reflect, I say, on these things, what do you think is my state of mind, MOST EMINENT CARDINAL — except that, while I comply with You, and render to the Most Christian King the service that, at Your persuasion, he decreed and commanded, there is hope that God, thrice best, approves obedience more than sacrifice, and therefore does not deny grace to me as I do what will be in me?

As for what remains: since the office which I discharge from now on is Royal, I do not make an end of speaking before, paying [Greek: not fully read [?]] to the best and greatest King, I pray for him every kind of (which indeed with all strength and with full vows I do) happiness from the King of Kings. And indeed how happy he is going to prove in the remaining course of the Reign, one may augur even from this: that all things have already, in this three-year span, turned out so prosperously. Of course, the heart of the King is in the hands of God, nor has the hand of the Lord been shortened so as henceforth to protect him less from Sion, to confirm his counsel less, to send help less from the Holy [place], to prosper all outcomes less. Born among lilies, he grows up among laurels, and is overshadowed by the tallness of victorious palms: what rich spoils, then, is he not one day to bring back, when he has reached the strength of Heroes? What monsters is he not going to tame, he who even in the cradle, like another Hercules, has accomplished such glorious deeds?

May we not, on other grounds, hope that he will be made equal to Solomon in wisdom, since — not even having awaited [his] second seven-year span (nor yet having passed it), but even through the first, which he recently completed — he has shown himself so composed that he has done nothing privately of the kind infants usually do, and nothing publicly that would not have befitted, in the highest degree, a man mature in age? May we not hope that, as in the times of Solomon, so in his days justice and abundance of peace will arise, since he is growing up amid desires for peace: and, from the very taking up of the sceptre, his most August Mother [Parens] has pursued such counsels about peace as are shortly going to turn out, with the Powers above favouring, well and happily?

[12] "non-nemo", literally "not no one", that is, someone, more than one person.

Is there not, then, great hope that, just as Solomon built the Temple on the mount, in which victims of Peace were to be offered, so he himself, besides the other monuments of his own piety, will restore and complete this Shrine, on this very mount, in which the ornaments of Peace are to be cultivated? The ornaments, I say — that is, the good Arts, and above all Mathematics itself, which so greatly befits even Kings themselves, and makes those by whom it is loved, fostered and cultivated known above the heavens; as so many Princes serve as an example, whose names, as though inscribed on the sky itself, endure as long as the sky.

There is certainly enormous hope that the Prince, who is to be most fortunate and most glorious both at home and abroad, will likewise inscribe his own name too, out of love for those same arts; and that, flying on the lips of men, and flourishing more and more every day, he will attain — which I vow — an everlasting fame of [his] name [nomnis] [recte: nominis].[13]

I have spoken.

Delivered on the day mentioned above, in the year 1645.

[13] *futurus* may also be taken with *Princeps* alone, "the future Prince", with "most fortunate … most glorious" then describing him directly.