Astronomiae Instauratae Mechanica

"Mechanics of the Restored Astronomy" — Brahe's illustrated catalog of his observatory instruments

(1602)

by Tycho Brahe (1546–1601)

Translation by Scott Weisman

Ars Astronomica

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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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ArsAstronomica@protonmail.com

A note on the work

A sumptuously illustrated catalog of the most accurate astronomical instruments built before the telescope, gathered on the island observatory of Hven. Each — the great mural quadrant, armillary spheres, sextants, and parallactic rulers — is shown in a finely engraved plate and described with its dimensions, materials, mode of use, and the precision it could achieve. The book also tours the celebrated observatories Uraniborg and the half-buried Stjerneborg. Part scientific manual and part proud self-portrait, it is the essential record of pre-telescopic astronomy at its peak.

A note on the translation process

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

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

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

[Front cover — vellum binding. No printed text. A handwritten ink mark (resembling a cursive shelfmark or numeral) appears in the upper-left quadrant; the glyph is not legibly resolvable [?]. A small paper repair tab is affixed near the upper-right edge, and a second at the lower-right corner.]

Tycho Brahe, *Astronomiae Instauratae Mechanica*

Title Page (engraved)

Diagram. The engraved title page combines the printed title (set above, in letterpress) with a full engraved frame surrounding a half-length portrait of Tycho Brahe. Tycho is shown in a fur-trimmed cloak with a ruff collar and a chain of office, standing within a round-arched niche, his hands resting on a ledge in the foreground. The arch and the two flanking pilasters are filled with the heraldic shields of his sixteen quarterings (eight on each side), each shield captioned with the family name of the lineage. A cartouche below the portrait carries the biographical inscription; two small panels at the lower corners carry a paired motto.

Printed title (letterpress, above the engraving):

> *TYCHONIS BRAHE* **ASTRONOMIÆ** INSTAURATÆ **MECHANICA.**

[Tycho Brahe's *Mechanics of the Restored Astronomy* (i.e., *The Instruments of the Restored Astronomy*).]

Coats of arms, left side of the arch and pilaster (read top to bottom):

- BRAHER [Brahe]
- RVDER [Rud]
- LONGER [Lange]
- ROSENKRANS [Rosenkrantz]
- AXELLSØNNER [Axelsen / Thott]
- MARCKEMAN [Markmand]
- KABBELER [Kabel]
- GVLDESTERE [Gyldenstierne]

Coats of arms, right side of the arch and pilaster (read top to bottom):

- BILLER [Bille]

- VLESTANDER [Ulfstand]
- RØNNOR [Rønnow]
- TROLLER [Trolle]
- LONGER [Lange]
- ROSENSPAR [Rosensparre]
- STORMVASER [Sture / Sparre]
- AXELLSØNNER [Axelsen / Thott]

[?] Several of the heraldic surnames are spelled in an idiosyncratic engraved orthography; the modern equivalents given in brackets are the standard Danish/Scandinavian noble houses of Tycho's sixteen quarterings.

Biographical cartouche beneath the portrait:

> EFFIGIES TYCHONIS BRAHE OTTONIDIS DANI, DÑI DE KNVDSTRVP ET ARCIS VRANIENBVRG IN INSVLA HELLISPONTI DANICI HVENNA FVNDATORIS, INSTVMENTORVMQ[ue] ASTONOMICORVM IN EADEM DISPOSITARVM INVE[N]TORIS ET STRVCTORIS, ÆTATIS SVÆ 40, ANNO DÑI 1586. COMPL[etae].

[Portrait of Tycho Brahe, son of Otto, a Dane, Lord of Knudstrup and of the castle Uraniborg, founder, on the Danish island Hven in the Sound, of the astronomical instruments arranged there, and their inventor and builder; at his age of 40, completed in the Year of the Lord 1586.]

Paired motto panels at the lower corners:

- Left panel: NON HABERI [Not to be esteemed]
- Right panel: SED ESSE [But to be]

[The two panels together read *Non haberi, sed esse* — "Not to seem (esteemed), but to be."]

Imprint (letterpress, below the engraving):

> NORIBERGAE, apud LEVINVM HVLSIVM. ANNO M. DCII. Cum Caesaris & Regum quorundam Privilegiis.

[At Nuremberg, by Levinus Hulsius. In the year 1602. With the privileges of the Emperor and of certain kings.]

[Title-page verso: blank. Only the show-through of the engraving on the recto is visible; no text is printed on this side.]

To the Most August Emperor Rudolf II — Tycho Brahe's Preface

AD AUGUSTISSIMUM IMPERATOREM RUDOLPHUM SECUNDUM TYCHONIS BRAHE PRAEFATIO.

[To the most august Emperor Rudolf II [Rudolf II, Holy Roman Emperor], the Preface of Tycho Brahe.]

Astronomy is the most ancient of the sciences, granted by God to the human race ever since Adam, the first-formed man, and by far the most excellent — excellent precisely in the degree to which the heavenly and sublime things surpass these earthly and inferior ones. This divine astronomy, I say, takes its origin from the very evidence of the eyes, as men observe the ever-shifting vicissitudes of the stars; and so, from the earliest creation of the world, it has long exercised the talents and genius of the most outstanding men in the pursuit of things beyond ordinary reach. So great, indeed, is the majesty of God, the Best and thrice-Greatest, that the wisdom of his works can be exhausted by none of his creatures.

Since mere ocular inspection could not grasp, with the subtlety and accuracy the task demanded, all the mysteries of that theater of the heavens — so far beyond our wonder — together with their intricate apparent variations, craftsmen in every age devised aids and instruments to assist the sight in perceiving the hidden motions of the stars. To this purpose belong those famous columns which Josephus, the historian of Jewish affairs, reports that the descendants of Adam set up in Syria, inscribing upon them, for the sake of posterity, the knowledge they had discovered. Here belong too the Egyptians' — and other peoples' — towering and immensely costly pyramids, and many other structures built for this use by the most ancient kings: such as could once be seen in India, Syria, Arabia, Chaldaea, Ethiopia, and Egypt, and especially in the Alexandrian portico there, and elsewhere too in the surrounding regions, wherever men lived diligently intent upon the science of the stars.

For this is the first requirement of all: that in astronomy a great many long-continued observations be captured from the sky with instruments that are suitable and not liable to error. These are afterwards, by geometry, organized through suitably devised hypotheses into continuous quantities and into that circular and uniform motion which the heavenly bodies naturally and without cessation seek and perform; and by arithmetic, into discrete quantities — so that

the circuits and places of the heavenly bodies may be established for any given time.

Among all those who have labored strenuously in this field, the only records that have reached us are those set down by Timocharis, Hipparchus [Hipparchus], Ptolemy [Ptolemy], al-Battānī [al-Battānī], King Alfonso [Alfonso X], and, in the more recent age, Copernicus [Copernicus] — though for the two earliest of these the tradition survives only through some account given by Ptolemy. As for the instruments these men chiefly used in measuring the phenomena of the stars, this is in some measure clear from their writings. Among these I find three principal ones: the parallactic rules [Regulae Parallaticae], the zodiacal armillae [Armillae Zodiacales], and the torquetum [Torquetum] — which was rather more in use among the Arabs (as were also the plane astrolabes). The rest are of lesser importance. There were, perhaps, many other instruments which, not committed to writing, never reached us; and which, amid the great and frequent confusion and upheaval of the world's stage — with so many wars and devastations creeping in one after another — could easily (and this is to be lamented) have perished.

More recent astronomers added the quadrant, the cross-staff [Radius], and the astronomical ring [Annulus Astronomicus], and also certain devices of still slighter value. But since the motions of the stars, accurately considered in our own age, by no means present themselves as the calculation derived from the observations of any of those craftsmen — whether ancient or recent — would have it, this not without reason

raises the suspicion that the means and instruments they used in observing were not everywhere free of every fault. This is sufficiently proved even by the fact that the positions of the fixed stars, relative to one another, are arranged otherwise than the Hipparchian record reviewed by Ptolemy — and propagated from there down to us — would have it; and this even if everything else be passed over. So true is this that not even among the ancients, where emperors and kings generously furnished the funds for constructing such instruments — so that they might be made magnificently of solid and metallic material, and might be of a fittingly suitable size — was this fault absent; still less in the case of those instruments which Copernicus procured in the preceding age at his own private expense.

That these were not sufficient, either in solidity of material or in a magnitude proper to the uses for which they were intended, is partly clear from his work *On the Revolutions* [*De Revolutionibus*], and partly from those of his instruments that

still survive — among which one, a parallactic instrument, plainly of wood and hardly fit for observation, is in my own possession.

For these reasons I began, from my youth, to ponder very anxiously whether this defect could not be remedied. Then, gradually, I had various astronomical instruments constructed, with incredible diligence and expense, by which it might be permitted to investigate the appearances of the stars more exactly than has been done by our predecessors (let it be said without envy). Although those I made in my youth — when neither my knowledge nor my judgment was yet mature — did not very exactly attain the mark aimed at, nevertheless, as a more serious age came on, together with more frequent experience, I took care at last to have other, greater and more excellent instruments invented and skillfully wrought: such as scarcely any earlier age perhaps has seen, instruments which accomplish what is intended with the highest precision and certainty.

I built them various and manifold, and that for evident reasons. First, so that by examining the same object in different ways I might confirm an observation to be free of all error; and also so that, if any one of them should contract some hidden flaw (a thing of which Ptolemy too seems to complain, concerning certain instruments made of solid metal which once stood in the Alexandrian portico), another would at once be at hand to correct it and to test its exact certainty. Furthermore, so that the keenness of the observers — of whom at the very least six or eight are needed — in sighting, and their diligence in counting, might be compared and examined against one another, with none of them aware of what another had found; and (to say nothing more) so that the very variety might make the observers more diligent and more eager, and might delight them in itself.

There is this, besides: that since among the things which fall to be observed some are better investigated by these instruments than by others, according to the suitability of the machines — some requiring only known altitudes, some these together with azimuths, some demanding distances alone, some declinations, some requiring equatorial distances, others serving for longitudes and latitudes, and others again suited to obtaining right ascensions and declinations simultaneously, and so on for the rest, if there are yet more things that serve celestial observation, to be carried out in whatever manner — for this reason alone the abundance and variety of instruments is altogether necessary.

But since the things devised and elaborated by men for the use of the arts ought to be of common benefit — for the sake of the kindly fellowship of the human race and the propagation of the arts to posterity — I judged that I ought not to

reserve such lofty and useful inventions for myself alone, but should share them also with others, if any be found anywhere (as I hope) whom so arduous a concern touches. And therefore I have resolved to commit to the press, and to send forth into public view, those instruments which I have used up to now, drawn and represented in figures (so far as could be accomplished so quickly), with a concise explanation of each added, as will appear in what follows.

In arranging them I have observed chiefly this method: that I set first those which examine the altitudes and azimuths of the stars — some of them disclosing only altitudes, others both these and azimuths; here too the lesser ones precede, like preliminaries to the principal ones. The more august instruments, which afford exact precision, follow after; and with these the first eight instruments are completed — though, last of all, I shall display and mention a certain very large quadrant, intended only for altitudes, which I once used at Augsburg [Augsburg] in my youth. Why this was done will be told afterward.

Next follow the armillary instruments. Among these, first it has the zodiacal armillae, which exhibit the longitudes and latitudes of the stars with greater convenience and certainty than was perhaps done by the ancients. But since these, for certain reasons set out in that place, do not touch the whole matter exactly (as the saying goes), three other equinoctial armillae follow: of which the first consists of three circles together with an axis, the second requires four together with this. The third and largest, content with a sesquialteral [one-and-a-half] circle and an axis — as in the others — dispatches the whole business, and reveals both declinations and right ascensions, together with the distances from the meridian, most subtly.

In the third place I have arranged those instruments which serve for probing the intervals between the stars; and this both for the greater

Preface (to the Emperor), continued

both for the greater intervals and for the lesser, provided only that the distance does not exceed a sixth part of the circle. There ought to be four such instruments for measuring these distances, though I have several more ready to hand which could not so quickly be drawn and engraved. Among them is one that reaches even to a sixth of the circle for the remoter positions of stars, but for stars closer together it brings the measurement down to within an even smaller arc [recte: it draws the measurement of nearer stars into a yet smaller part — i.e. it measures close stars more finely].

Lastly, an instrument which I used in the new and exceedingly wonderful star of the year 1572 — set up to mark its altitudes, especially in its lower position [in situ declivior] — has been added out of the original order. So too has that great quadrant I mentioned earlier, which I had built more than [?] years ago near [Augsburg] in the garden of Consul Paul Hainzel [Pauli Hainzelii], of excellent memory, who while he lived was most eager for these arts. Since it no longer exists, and lasted only five years [quinquennio tantum], I did not wish to grant it a place among the other instruments meant for surveying altitudes, but set it at the end on that account. And after it comes a certain steel quadrant [Chalybeus Quadrans], of which I treated among the earlier instruments, though it is arranged differently there.

Once these are dealt with, a brief description of other instruments of mine is at last appended — instruments not yet drawn or set out, which I have ready at hand — together with some indication of those I still intend to work on by a remarkable economy of means [miro compendio]. Of each of these, both those that are prepared and ready and the others, I shall give a fuller account in due time, as opportunity for working on them is offered; but for now, studying brevity — and since the figures of them were not at hand either — I have been content to touch on the few matters that concerned this business.

Finally, in the place of a colophon [Coronidis loco], I describe that very great globe of brass [Globus maximus Orichalcicus] which embraces a thousand fixed stars [mille stellas Fixas], restored by us with the utmost diligence and precision over very many years now past — fashioned in full, so far as a thing serving so laborious and manifold a use can be made clear in few words. And with this I set an end to the description of the instruments.

To all of these I append some account of the things accomplished by us up to now, and of those that remain to be completed hereafter, with a few letters of distinguished men added, recommending the undertaking we are attempting. Moreover, in the place of an appendix, I have thought it worthwhile to add as well the architectural works [Architectonica opera], represented and explained, which reveal to the eye the structures arranged and built by me for these uses some years past. Although this might seem to some not very necessary in this place — since those who are willing to give serious attention to such matters, and are equal to providing the costs, will easily discover for themselves the plans of the buildings suited to the purpose, especially once a convenient site is secured — nevertheless, that I might offer some idea of these things in keeping with what we have continually worked out concerning the matter, I judged it not altogether

beside the point to include these astronomical buildings, represented here together with the rest.

These, then, are roughly the contents by which this book is rounded out, as will become plain to anyone who looks within. If anything else has been interspersed or added, the prudent reader will discern it without difficulty by himself, so that he has no need of an admonisher.

To you indeed, most august Emperor [Rudolf II], the Second of that name, most clement Lord, I offer, dedicate, and consecrate this and our other astronomical labors, with a submissive spirit and a zealous intention toward the public good. For your Imperial Majesty, just as by its supreme preeminence it far surpasses other and lower men, so too you are not unaware that it befits the dignity and office of an Emperor to emulate Heaven and the heavenly things, which surpass earthly and common things beyond measure; and therefore that these sublime studies are to be held in honor and fostered. The ancient poet [Manilius] seems to have had this in view when, writing of this heavenly Art and addressing [Augustus], the second Monarch of the Roman Empire, he adorned it — not undeservedly — with this tribute:

> First it deigned to move royal minds, as they touched the summits of things nearest to Heaven. [*proxima tangentes Caelo fastigia rerum*]

To you therefore, most august Caesar, I commend these things which for many years now, almost from boyhood, with tireless labor and incredible expense, I have toiled at — so that that divine and most especially royal science of astronomy, holding the foremost place above all others, might at length be restored to wholeness, and handed down to posterity more accurate than ever before. Once these are clemently accepted, I am confident that both I myself and these very studies which I treat — distinguished as they are — will be most highly commended for the future: so that the honor and Majesty of God, the Greatest and the Best, which shines forth in the heavenly things above all the visible things of this most ample theater of the World, may more rightly become known, and so be the more cherished and revered among the dwellers on earth. And further, that the memory and fame of your Caesarean Majesty — because it does not disdain to preserve, protect, and promote these things, so excellent and well-nigh the chief among worldly matters —

may shine the more illustriously and endure to all posterity, as long as the Sun and the Stars shall last. For from these things alone, which are perpetual and constant — such as the heavenly things are — a perpetual and constant name and

honor is gained. All other things, sublunary and earthly, just as they are subject to manifold changes, so too whatever glory is gotten from them is fleeting, wandering, and inconstant, no rival of eternity — unlike these heavenly things of which I speak.

May the supreme and incomprehensible Author of these things deign to grant to your Caesarean Majesty a good mind, health of body, peace, and an abundance of the good things of this world, together with a tranquil and happy reign — chiefly to His own glory and to the illustration of the things He has created, and to the benefit of your subjects. This I humbly and heartily pray and vow. Farewell, your Imperial Majesty, and may you clemently accept this small New Year's gift [strena] of this new Year, which I present, to the best of my ability and with a submissive spirit, with what reverence I can.

Given from the Rantzau Castle at Wandsbeck [Arx Ranzoviana, Wandsbeck], which is near [Hamburg] on the borders of Germany and the Cimbrian Chersonese [Cimbrica Chersonesus], on the day before the Kalends of January [31 December], in the Year of the Christian Vulgar Era 1598 [cIↃ.IↃ.IIC].

To the Noble Gentleman Tycho Brahe of Knudstrup (commendatory poem)

[Body heading, p. 11:] TO THE NOBLE GENTLEMAN **TYCHO BRAHE OF KNUDSTRUP** [Tycho Brahe], HIS MOST LONGED-FOR KINSMAN AND RELATION.

AGAINST THE ZOILI [Zoilos — carping detractors], THE MALEVOLENT, AND THE IGNORANT.

> The hidden things of Urania [the heavens], though neglected and remote, which it is granted to the great Gods to inhabit in the lofty Aether, the unknown ways of Heaven and its everlasting motions — while it is permitted to know them, to you, Tycho, disclosing those sacred things, [Heaven] beholds itself wheeled about its lofty axes. And yet the unknowing and envious crowd, lingering nonetheless, with sneers receives it, and — with a dullness not yet pierced by any solid understanding — carps, harasses, plots deceits and tricks; it contrives unjust schemes, and hurls unspeakable weapons — but they break themselves against a solid shield, illustrious labors which it might perhaps hope to disturb. It suffices that to itself virtue is, from every side, always enough, nor does it pause over the empty trifles and manners of men. Behold, you now bring forth Instruments (a wondrous thing)

> conformable to the divine sacred rites, by which you yourself, by your own genius, can subdue the lofty Heaven. Be gone, you profane: [*Procul ite prophani*] These are the rivals of virtue, the rivals of the Gorgon's countenance, these are even greater things: for the bright things [the stars] do not care from where they kindle the envy and hatred of base minds, ill-conscious of evil. At last, struck by this very sight, these too, like stones, stand amazed, are stunned, fall silent, and grow rigid. Indeed, who would deny that the ignorant, to whom these divinely-inspired things [Enthea] are so worthless, are mere stumps, and brute beasts in the body of a man? But you, Tycho, planted in the lowest inmost depths reach up to the heights; and what you do — you laugh from on high at the follies of the World, at the unclean tumults and the lowly hearts, ignorant of their lot, which Dives [the rich man / Dis] dispenses along a just course; and standing firm in the shoal you scorn the floods, the rains, and the blasts.

OLIGER ROSENKRANTZ [Oliger Rosenkrantz / Holger Rosenkrantz], son of E. [C. F.], of Rosenholm [Rosenholm].

QUADRANS MINOR ORICHALCICUS INAURATUS — The Lesser Gilt Brass Quadrant

[Body heading, p. 12:] **QUADRANS MINOR ORICHALCICUS INAURATUS** [The Lesser Quadrant, of Brass, Gilded]

Diagram. An engraved plate showing the lesser gilt brass quadrant. The instrument is a quarter-circle (90° arc) graduated along its outer rim, mounted on an ornate turned pillar that rises from a circular tripod stand resting on the ground (with small plants and rocks at the base). The quadrant arc occupies the upper left; a vertical graduated bar with numerals runs up the right side; a plumb bob hangs from the right. Labeled elements:

- D (top of the arc, upper left): terminus of the quadrant's graduated arc near the sighting edge.
- E (upper-right frame corner): head of the right-edge graduation column.
- H (within the arc field, upper center): a point/figure within the body of the quadrant.
- L (right-center, within a circular medallion/cartouche): an allegorical figure within a roundel.

- L (second occurrence, on the same roundel mechanism): the engraving labels two parts of the same small ringed roundel device — genuine doubling, not a misread.
- I, K (lower center of the arc, near the apex): points at the lower vertex region of the quadrant.
- B, M (lower left, at the foot of the arc): terminus of the arc at the horizontal limb; M marks a small pivot/fitting with a fixture.
- N (along the lower horizontal bar, center): point on the horizontal limb.
- A (lower right, end of the horizontal limb): corner of the frame; F just above it (right end of the horizontal bar, foot of the vertical graduated scale).
- F (right side, foot of the vertical scale): junction of horizontal limb and vertical graduated bar.
- Q (below the lower-left arc foot): a small pendant fixture/weight with the brace running up to M.
- G (lower right, hanging): the plumb bob [perpendiculum] suspended on a line from A.
- P (on the supporting pillar, below the instrument body): top of the ornamental column where the instrument seats.
- N (on the pillar, center): shaft of the supporting column.
- R, R, R (around the upper ring of the tripod cradle): scroll-bracket supports.
- S, S, S, S (on the cradle ring): floret/rosette fittings at the joints of the cradle.
- T, T, T, T (around the lower disc of the stand): points on the circular base-plate / leveling ring.
- V (lower left, on the base disc): point on the rim of the round base-plate.
- Y (lower right, on the base disc): point on the rim of the round base-plate.
- X (lower base band / pedestal): point on the lower base disc beneath the leveling ring.
- Z (on the turned foot/pedestal below the disc): the central baluster foot of the stand.

The vertical graduated scale on the right edge bears a column of numerals reading downward; the figures (top to bottom) are: 89, 84, 79, 72, 67, 61, 57, 53, 50, 49, 47, 46.

[Below the plate, lower right:]

Account of the Construction and Use [Explicatio Fabricae et Usus]

This quadrant is not large. I had it built many years ago, in the form shown here. It consists of a solid plate of fairly thick brass [Orichalcum], measuring one cubit from the center A to the circumference B D C. It is entirely gilded, by the action of gold, mercury, and fire, so that it stays more handsome and cleaner, and is not subject to the corrosion to which brass is otherwise liable unless frequently polished — corrosion that gradually eats into and fouls it.

Its outer limb B D C is subdivided in the ordinary way, at the least into 90 parts, and each of these again into 12, so that this subdivision shows individual divisions of five minutes each. Within this lies another division, the one that Petrus Nonnius [Pedro Nunes], the most distinguished Spanish mathematician, set out in his learned little book *On Twilights* [*De Crepusculis*], supposing it to have once been used by Ptolemy — though this scarcely deserves belief. It is of this kind: within the outermost quadrant other smaller ones are drawn, fewer in number — 44 — accompanying it in succession, of which the outermost is to be divided into 89 parts, the next into 88, the third into 87, and so on, until one arrives at the last and innermost, which will have 46 divisions, just as these are somehow represented in the figure itself.

Its rule [Regula] D A has sights [pinnacidia] at A and D, fitted in the ordinary way with apertures. Yet at the lower one, near A, slits can sometimes be applied as parallels; at the upper one, in our own manner — so that the sighting [collimatio] may be made easier and more exact. The plumb line [perpendiculum] E F G is suspended from the rear part, so that by its means one may know when the quadrant has been correctly set up: that is, when its lower side A B is at equilibrium with the horizon, while the other side, A C, looks exactly to the zenith of the heads, and the whole plane of the quadrant coincides with the plane of some vertical circle.

The quadrant is set correctly in this way: partly by means of the screws which it has near the lower arrangement of the pedestal [Pedestal], marked with the letter S, and partly by the screw at O M, which raises and lowers the whole quadrant until the plumb line shows that it is suitably positioned. For it stands on the pedestal N M O P Q R S T, which — together with the other requirements — I consider best made of iron. At the rear, near H, it is fastened to it; and near N this support is somewhat movable, so that the quadrant can be moved up and down by the screw O M. For the iron rules M N and O N can be drawn together and

widened apart by means of the intervening screw O M; and so the quadrant can be raised or lowered a little, as need requires.

It is also turned about in the curved channel N P, toward whatever quarter of the heaven one pleases, while the whole lower part of the pedestal — marked by the letters R S Q T — stays fixed. That lower portion, by the form you see, provides supports so that the quadrant may stand firmly on its four screws indicated by the letters S T; these screws (as I said) direct the whole instrument to its proper position. These screws rest on little iron plates near T; and while these are at rest, the screws can be turned freely on a certain table V X Y Z, as one pleases. And let these things be said in a general way about the quadrant and its pedestal.

As for what is seen, to some extent, within the center and the smallest quadrant — a picture L K enclosed in a circular form — it has been engraved for the sake of ornament, and also so that by its hieroglyphic [Hieroglyphica] meaning it might teach something, since otherwise that space would be empty. In this figuration (so that I may note this too in passing): beside a tree that is green and leafy on one side, a young man crowned with laurel sits on a squared stone, holding in one hand a celestial globe and in the other a book, stretching out his feet on the green grass and herbs that cover the root of the tree. On the other side — that is, the left part of the tree — the root is withered, and the branches are barren, lacking leaves; and among them stands a table holding objects each made of iron [?] — that is, the things that on this earthly stage are prized by mortals: such as a strongbox full of coins, scepters, crowns, ancestral coats of arms, golden chains, gems, a lady's mirror [Mundus muliebris], cups, papers, dice, and the like. A certain skeleton, representing death, surrounds all these with its hands and feet, as though to seize them.

Above is written, for the whole figure, a hemistich that explains the allegorical sense: *VIVIMUS INGENIO, CAETERA MORTIS ERUNT* ["We live by our genius; the rest will belong to death"]

—so arranged that the first part of the hemistich hangs as if on a written scroll from the branches at the right, on the green side of the tree, where that philosophizing young man sits, while the following part of the hemistich is the other portion. By these we wished to suggest that sound learning — especially the sublime knowledge of celestial things — bestows on this earth permanence of life and memory; that all else is frivolous and fleeting, and perishes together with the man's body.

But when we look toward the eternity of the Kingdom of Heaven, then these very things which are now on the green side of the tree pass over to the latter side — since there is no proportion between the finite and the infinite. Then the inscribed hemistich is changed otherwise, namely thus: *VIVIMUS IN CHRISTO, CAETERA MORTIS ERUNT* ["We live in Christ; the rest will belong to death"]

—so arranged that the first part fits the green tree, the other the barren tree. Within the green face of the tree there is a certain hieroglyphic indication of the life and teaching of Christ. The rest remain as before, except that human teachings and inventions also turn toward the left and rear

—the rear part of the tree, that is, toward the barren part. By these we suggest that nothing can confer on a man blessedness and immortality unto eternity except the merit of the Son of God, Christ the Redeemer, and the observance of His teaching and life. All these things I have chosen to set out here, even if perhaps beside the point, on account of the attached picture.

On the other side of the quadrant a small canon [Canon] is engraved, which with the least trouble shows what each of the Nonnian points (of which I spoke), belonging to the division, presents in the altitudes sought.

The **use** of this quadrant is in taking the altitudes of stars and luminaries, when the utmost precision is not required — that is, when it suffices to know this within two or three minutes. Let the plane of the quadrant be directed toward the star to be observed and correctly arranged by its screws, as said before, until the plumb line shows that everything is rightly set. Then let the rule A D be raised or lowered until the star is seen through the apertures or slits of the sights, or the light of the Sun is admitted exactly. And so let it be fixed on the other side, near D, where it has a little screw hidden here. For thus, in the outer limb, where the divisions are ordinary, the outermost part of the rule will show the altitude sought to within five minutes — of which one may also attain, by accurate observation, the half or the third part.

But if you wish to use the Nonnian division, you must see at what point the rule crosses one of its points, wherever that may be, and count which point it is, and how many other points that quadrant contains; with these two numbers you must enter laterally into a table engraved on the other side of the quadrant, and so, in the area near their common intersection, are found the degrees and minutes giving the measured altitude. The same is accomplished, without the table, by the rule of proportions [Regula proportionum], with no great labor: by placing in the first position the total division of that quadrant in which some

point is touched by the rule itself; in the second position the degrees, 90; in the third the number of that same point from the beginning up to where the rule is; and so the fourth, the usual operation being performed, will show what is sought. But this Nonnian method is not sufficient in practice, nor does it hold in reserve what it promises at the outset — as will be clear to one who tries it.

QVADRANS MEDIOCRIS ORICHALCICUS AZIMUTHALIS

The Medium-Sized Azimuthal Brass Quadrant

Diagram. An engraved plate of the medium-sized azimuthal brass quadrant. The upper portion shows the graduated quadrant arc (the curved edge bears a graduation scale numbered in 10° decades; legible station figures include 0 at the apex, 60, and 80), with a long sighting rule running diagonally from the lower pivot up across the arc. The arc and rule are mounted above an elaborate azimuth assembly — a large horizontal graduated azimuth circle with scrollwork supports — resting on a multi-columned marble stand set on a tiled floor.

Readable labels:

- D (upper left, near the quadrant apex / sight assembly): the upper end of the arc / sight region
- V (base of the sphere assembly; recurs at the pedestal tops): pedestal/mount marker
- G (sight-assembly cluster): sight/index region of the rule
- E (end of the sighting rod, beside a hand-clasp ornament): the lower sight end of the rule
- N (left, at an ornamented finial atop the left pedestal): point on the chalybeate azimuth circle N O P
- R (center, on the meridian/horizon ring of the sphere): ring marker
- S (right flank of the sphere body): the bench or pedestal region marked S
- P (top of the right-hand pedestal): point on the azimuth circle N O P
- Z (face/base of the right pedestal): one of the marble columns
- T (floor, left): floor/leveling-plate marker
- Y (floor tiling): pedestal/column base

Account of the Construction and Use [Explicatio Fabricae et Usus]

This quadrant A B C, made of a solid sheet of brass, measures from the center to the circumference A B a little more than one and a half cubits. Its thickness is nearly a full inch [digitus] in width. Within the circumference it contains not only the division customary to us, by transverse lines and points (of which elsewhere), but also that Nonnian division of the most distinguished Spanish mathematician, set forth in his learned book *On Twilights* [*De Crepusculis*], which I mentioned in the earlier description — though here enlarged by another and more convenient method, so that it contains more subdivisions, especially of those numbers which can be conveniently distributed into some whole parts.

In this respect the Nonnian invention caused no small difficulty, since by itself it is not sufficient to make manifest all the minutes of the whole quadrant, much less the seconds of these, as he wished. For that has its place rather in calculation than in practice — as it often happens that beginners in this art are deceived in its use. There is also added a table engraved on the other surface of the quadrant, which illustrates the divisions and, without further calculation, renders them very easy for use.

Its rule D E is wholly of steel [Chalybs], so that it may always remain the more readily straight. But it is at the same time gilded, lest it be tainted with rust. The double sight [dioptra] around D E is of brass: at the lower end E it shows slits parallel to the upper sight at D, to which the eye of the observer is to be applied; so that the stars all around may be sighted, more in line with the first sight, centrally, and without any error. This is the method customarily used by us in all our instruments. And the rule itself has been deliberately made longer than the radius of the quadrant, at A K; partly so that with it the lower end at E may be easily raised and lowered by the fingers for sighting, until the exact altitude of the star being observed lies open, and likewise its azimuth.

This azimuth too, wherever it has been moved, may remain fixed: it is kept and held in place on the other side of the quadrant, around D, by a thin steel feather (as they call it), so that the observation may be the more exact and convenient. For it works out almost as if the quadrant had in its radius the length D E; and moreover, lest the lower supports get in the way, this manner of handling is more apt. And let these things suffice as a sufficient account of the quadrant itself.

The supports [Fulcra], of which I speak, are as follows. First, the quadrant itself turns, being fixed near H to a certain oblong, sturdy round iron, by a little screw, so that it can be removed when one pleases, in a certain channel which on the outside has the angle-shaped revolutions that appear, for the sake of firmness and ornament. The channel itself, fitted below with another rule represented near K and M, is conveniently revolved together with the plane of the quadrant above the chalybeate azimuthal horizon N O P; and at the same time, under the index K, the azimuth of the star is observed together with the altitude. It opens by the same operation, so that the altitudes are to be counted higher up on the quadrant (as has been shown), but the azimuths on the said azimuth circle.

The screws which are seen around the said letters — three of them, and also a fourth hidden on the other side — bring it about that by them the steel horizon can be set into the plane of the [true] horizon, and accordingly the quadrant standing above it can be directed correctly both according to the equilibrium of the horizon and toward the zenith on each of its sides. There is also another screw near F, which corrects it in the tiny little differences (where there is need), so that it may exactly represent the plane of any vertical circle in whatever its position. Furthermore, these steel screws — carrying the whole instrument — rest on four marble columns, three of which, visible, are indicated by the letters X Y Z. The fourth, on the rear side, equal to them, is not fully visible. Finally, within these four is contained a bench or pedestal marked by Q R S; onto which, the observation being performed, one ascends and stands, so that the altitude observed on the circumference of the quadrant may be counted conveniently and accurately. And let this suffice as an account of the construction of the instrument. The rest, if any tiny details are wanted, are easily learned from the figure itself by ocular inspection and diligent attention.

Its **use** extends very widely, in whatever direction, through the altitudes and azimuths both of the planets and of the fixed stars — whatever there is that can be adapted to astronomical observations, and reduced into numbers by the science of triangles [Triangulorum scientia], and made to serve the same. On this matter let the books of the practitioners be consulted, and also those things which we ourselves have commented here and there on these topics in our works, as the matter required — especially in the second volume of the *Astronomical Exercises* [*Progymnasmata Astronomica*], which treats luminously of the Comet of the year [']77. For in its observations [?]... it sets forth each thing distinctly, minute by minute, in the altitudes [and azimuths]...

having been set forth in these observations, and adapted to demonstration, the chief use of this quadrant has been [established]; since I did not then have to hand the other larger ones and instruments of another form, made later. It sufficed nonetheless that it exhibited the individual minutes sufficiently distinctly, both in altitudes and azimuths. It is also explained in the said book toward the end, on page 461, namely, and by three [?]...

In the three following [figures] this same quadrant is explained somewhat more fully through its various features, and at the same time the method of dividing the circumference by transversal points — a method most apt and most exact, which we were the first to apply to circular [instruments] — is set out at greater length and illustrated by a fine engraving. Indeed, its sight-vane [dioptra] is also depicted and explained there, on page 462, where the principle of the sights [pinnacidia] and slits [rimulae], of which I make mention from time to time below, together with their arrangement and everything else relevant here, is clearly shown. Therefore I refer the reader who is eager for these matters to that place; there too he will find much more bearing on the principle of this instrument [the *Mechanica*] as well as of the others — material that there was no room to record here. And what I have set out there concerning the division [of the limb] and the placement of the sights, I wish to be understood as applying to all the other instruments to which it must be adapted, so that there is no need to repeat it tediously either here or elsewhere.

This much at least, both on account of this instrument and the others, I will here point out: that they all ought to be made as perfect as possible, and that for this purpose skilled mechanical craftsmen must be employed — men who know, or can learn, how to fashion such work with mastery. And if they should fail at the first attempt (as the saying goes), let it not weary the builder to do the work over again from the start and to amend in every way whatever is found wanting, until the instruments are subject to no fault at all. Observation itself, when variously carried out, reveals this clearly enough to anyone of understanding. Hence it has come about that we have had to remake — not without great expense — most of the instruments exhibited in this book, two or three times over, indeed almost to manufacture them anew; mills too were built, to be turned both by horses and by flowing water led around them, so that the instruments might be finished on a lathe, though nearly in vain. Many other outlays besides, such as are not easily reckoned up in the instruments themselves, were expended to this end.

QVADRANS ALIVS ORICHALCICVS ETIAM AZIMVTHALIS.

[Another Brass Quadrant, Likewise Azimuthal.]

Diagram. An engraved plate showing another brass azimuthal quadrant mounted on a stout turned column with a square stepped base. The quadrant arc occupies the upper portion of the figure; its graduated limb runs along the curved edge with transversal-point subdivision and numbered degree markings. The quadrant is braced internally by a lattice of struts forming squares, and rests upon a horizontal azimuth circle, which in turn sits on a heavy horizontal table supported by leveling screws. A long sighting rule (alidade) with its sight-vane projects from the center toward the lower right, terminating in a knobbed handle. Labels read (with positions as they appear on the plate):

- B (top-right interior corner of the quadrant frame, at the top end of the graduated arc): terminus of the quadrant limb
- D (on the horizontal cross-strut below B): junction of the bracing lattice with the limb
- E (upper-left interior, on the radial strut near the arc): point on the graduated limb
- T (left edge, where the upper graduated arc meets the frame): upper terminus / pivot region of the alidade
- C (lower-left corner of the inner quadrant frame, left of F): center-side terminus of the limb [Centro A ad B vel C]
- W, X (paired on the left interior triangulation panel): bracing struts of the quadrant frame
- V (interior, below T on a radial strut): strut of the frame
- K (left end of the inner graduated cross-bar, just left of P)
- P (center of the inner bar, immediately right of K; carries a small pinnule/pointer triangle ▲ above it)
- Y (on the inner bar, to the right of P)
- F (center of the horizon ring's near edge, below P): corner of the squared adaptation [Quadratum A D E F]
- L (to the right of F): center from which the rule runs toward the screw Y
- A (on the alidade arm near its pivot/center): center of the quadrant [Centro A] — a second small A also appears lower on the arm, near O (genuinely two A-glyphs, not a misread duplicate)
- O (on the alidade arm, right of A, near where the arm crosses the right frame upright): point on the sighting rule

- S (far sighting end of the alidade — right vane / pinnule, bottom-right): handle / sight-vane terminus of the alidade
- Z (on the horizon ring below the arm, right of H): point on the azimuth circle / screw region
- H (on the horizon ring, left of Z): point on the horizontal azimuth circle
- N (on the lower clamp / screw block beneath the ring): leveling screw [cochlea N]
- M (left-side clamp / micrometer screw assembly): leveling screw [cochlea M]
- G (on the horizon ring, below the F cluster): the horizontal azimuth circle GHIK beneath the quadrant
- Q (open interior field below the ring): the squared stone / table block somewhat hollowed at the sides [lapis Quadratus Q]
- R (the turned baluster column / pillar): the stone column on which the whole instrument rests [columna lapidea R]

Main quadrant limb (top arc) graduated 0°–90°, labelled at 10° intervals (read directly: 20, 30, 40, 60, 70, 80); fine subdivision hatching between the tens marks.

This quadrant too, ABC, is made of solid brass; but it is differently arranged, as appears in the figure, having beneath it the horizontal circle GHIK, which is also of brass, that contains and supports it. Now the parts of the whole instrument, each set out in turn, are as follows. From the center A to B, or to C, the length is one cubit and a half. Hence the circumference BC is evident; this too, in our accustomed manner, is subdivided by transversal points into the single minutes of the degrees, and it employs no other mode of division, such as the earlier one, since the limb is not made so wide as to take in conveniently a greater number [of points]. Nevertheless it has a breadth of about two finger-widths, and is capable (as I said) of expressing the single minutes transversally.

As for the square that is seen within the area of the quadrant, ADEF, together with the markings running across that fall upon it, these are fitted to it at least in place of a bracket [fulcrum] and for greater firmness — except that this square can also serve in geometrical measurements, both of the height and the breadth of objects that are seen on the earth and have been raised up there by human labor. Just as that instrument which Peurbach [Peurbachius] called the Geometric Square [Quadratum Geometricum] yields these and similar [results]: a subject set out and demonstrated by that same distinguished man in a special little book, and likewise by others who explain astrolabes, especially as regards its (so-called) reverse [dorsum] — though that is indicated with less trouble and not so exactly.

The other adaptation, which is seen in connection with these matters and is to be understood on the rear part of the quadrant, represents the form of the letter Y, and is marked with these three letters F[P]XY — placed there so that the quadrant's plane may be set at a right angle to the horizon, into which it is folded, however it may be turned about; and, on the side where it joins the horizon near Y, it is fixed by a certain small screw, where need is, so that, remaining motionless in its place there, it may conveniently indicate the azimuthal degrees.

There too a certain rule, drawn from the center L toward the screw Y, joins the lower extremity of the bracket with the lower and middle part of the quadrant, so that everything may cohere the more firmly and be turned about together; a small plummet too is added below at the screw, so that the quadrant may settle in any position whatever without any wavering, motionless. But that this quadrant is not solid over its whole surface, but interrupted, having for the most part quadrilateral [openings], which are seen in it open to view — this affords the advantage that it is of lesser weight, and on that account can not only be handled more easily, but also carried from one place to another (which too is part of its purpose), as we shall set out more fully hereafter.

Concerning its rule too, bearing its sight-vanes [dioptrae], we shall speak presently — once we have first explained some things about the azimuthal horizon; since those sight-vanes serve the observation of altitudes as well as of azimuths alike. Therefore the rule itself, with its rather oblong and broad plane, lies everywhere against the plane of the quadrant too: so that even in its lower part, where it projects beyond AS, it may touch the same plane exactly, and the sight-vanes with their sights may be at an equal distance from it, and may also stand upon it orthogonally; otherwise an accurate investigation of the azimuths (not to speak of the altitudes) could not be made.

But the azimuthal horizon (of which I have spoken), lying below the quadrant and thus supporting it, is expressed by GHIK, having within itself crosswise braces set at right angles, so that it may remain the firmer; and about the common [points] of these angles — namely at the center of the same horizontal circle — the quadrant, wholly fitted in there, turns within this channel. It has besides, near the extremities of those bracings, four screws MNOP, by which the wheel — the horizon, and so the quadrant itself resting upon it — are so directed that here it may exactly imitate the plane of any vertical circle whatsoever, and there the equilibrium of the horizon: which double use serves both for altitudes and for azimuths.

The rule (of which I made some mention before), applied to the quadrant itself, SVT, behaves in the same way as regards its sight-vane and sights, just as was indicated in the earlier [instrument] — except that below, near the sight-vane S, it has two handles, by which it can conveniently be raised and lowered by hand, as the altitude to be observed requires; and also so that by its own weight it may hold the other part of the rule, TA, as it were in equilibrium. For the rest, the whole instrument rests upon a square stone somewhat hollowed at the sides, for the sake of more convenient use, which is expressed by the letter Q. And this in turn rests firmly upon the stone column R, as the figure here sufficiently shows.

This quadrant has, beyond the preceding one, this convenience in its construction: that both it and the horizon on which it rests, and all the rest belonging here, can easily be disjoined and again be put together among themselves — so that it is suitable for transport from one place to another, into a convenient case; since it also does not consist of so many parts as the former, and these, by means of the screws disposed here and there, admit not only of disjunction but also, just as readily, of being recomposed exactly as before. And therefore I am accustomed to call this the Portable Azimuthal Quadrant [Quadrantem Azimuthalem portatilem].

Its use is uniform with the earlier one in all those matters which are to be observed through altitudes and azimuths, geometrically demonstrated, and hence resolved into numbers. We must nevertheless know that not too much is to be entrusted to these two quadrants in cases where the most exact observation, down to some minute fraction, is required — such as those that serve the restitution of the Sun's course, where the matter turns upon the smallest quantities, and demands a precision of a sixth, or at the very least a third, part of one minute; which instruments so small, embracing only one cubit or a cubit and a half, cannot deliver. Therefore let us now betake ourselves to larger and more suitable ones, which will accomplish not only this subtlety required in the case of the Sun, but also the tracking out and discrimination of the very smallest parallaxes [Parallaxium minutissimarum] (if any such there be) in any celestial phenomenon whatever, and will likewise disclose with scrupulous care many other things in the observations of both the wandering and the fixed stars.

Examples of such parallaxes the eager students of these matters will find in the second volume of our *Progymnasmata* of the Astronomy to be Restored [*Astronomiae Instauratae Progymnasmata*]; where, both in the former and in the latter part, I treat carefully of the Comets seen within the past 20 years, and investigate their parallaxes, as far as they could be had, most subtly, and

demonstrate geometrically and infallibly that they all arose in the aetherial region [Aetherea Regio] far above the Moon — so that there is no lack of men, among those who have come forth from the school of Aristotle [Aristoteles], who, though the truth has been more than sufficiently laid open (as also happens elsewhere in the varied opinions of men), are unwilling to acquiesce in it. Yet the truth must none the less be shown. Let those believe who acknowledge it and are willing.

Sextans Astronomicus

SEXTANS ASTRONOMICVS, PROVT ALTITUDINIBUS inseruit.

(The Astronomical Sextant, as used for altitudes.)

Diagram. A large astronomical sextant mounted for taking altitudes, shown standing on a low platform within a framed engraving. The instrument is a sixth-part of a circle (an arc of 60°) built from broad metal-faced limbs, braced internally by a lattice of crossed struts radiating from a central hub. The arc runs across the top of the figure between the two upper corners; the whole frame is carried on a heavy ornamental wooden pedestal that rests on a base-board lying on the platform. Labelled elements (positions as drawn):

- B (upper-left corner of the arc): one terminus of the graduated arc.
- A (upper-right corner of the arc): the other terminus of the graduated arc; the arc B C runs between these with its subtended chord.
- L (top center, on the arc): point on the upper limb / cross-brace junction.
- E (upper middle, near the hub): label on an upper strut near the central boss.
- D (middle, left of center): junction point on the radial bracing.
- N (middle right): label on a radial strut.
- M (left side, lower): pivot or sighting point on the left limb.
- G (center, below the hub, on the vertical member): junction near the foot of the central column.
- C (center, just right of G): the apex/center of the sextant where the limbs converge (vertex of arc B C).
- K (center, below G): point on the pedestal head [?].
- F (center-left, on the pedestal): point on the ornamental pedestal.
- I, I (flanking the pedestal, left and right): brace feet / struts to the base.

- H (lower left, on the base-board): one of the foot-fittings/clamps on the base.
- H (lower right, on the base-board): another foot-fitting.
- H (center, on the base-board, lowest): the central foot-fitting at the base of the column.

EXPLICATIO FABRICAE ET VSVS.

(Explanation of the Construction and Use.)

Since an astronomical instrument of this kind is extremely well suited to practical use, I was the first to devise it, more or less twenty years ago — so much so that I claim the invention as my own — namely, one that takes in the sixth part of a circle along its circumference. For observations of the sort that can usually be made, this is entirely sufficient, it does not make those observations any more difficult through excessive bulk, even though others have since appropriated the invention to themselves, and, with some variation of form, have not been shy of laying claim to it in various parts of Germany, and indeed of marketing it elsewhere too, as something of their own. I myself built three instruments of this kind in succession (as I shall say of others designed in different ways), having the same outer limbs and graduation arranged in the same manner, but with their internal bracing constructed variously, as convenience dictated. The present one, however — the one I am now speaking of — was the simplest of all in its bracing, since for that reason it can be carried with fewer attendants. For it was built for this purpose, so that it could conveniently be jointed together and packed into a chest at fixed points by means of screws, and, once placed in the chest together with its own stand, could likewise be broken down into parts. In this way it can be conveyed into other regions — at least, not only by sea (if that were safer) but also overland by carriage — and so the altitudes of the pole can be accurately explored in various lands. For this instrument serves aptly (as I said) not only for measuring the distances between the Sun and the stars, but also for taking their altitudes. When their altitudes need to be taken at greater elevations, the present figure shows how it is then to be set up.

Having now explained its construction first, we shall afterwards indicate its use briefly. This sextant A B C is everywhere coated with metal plates, and is so well finished that one may truly call it cast of solid orichalc, with no joint anywhere apparent. From the center to the circumference it measures four cubits. Near the center is a cylinder A, by whose means the intermediate observations are made

by the lower sight-vane on the rule A N M; and the upper sight-vane is set at such intervals apart as the diameter of the cylinder requires, so that the observation may be made from one side and the other in parallel, and may be marked off at the center without error. The graduation of the circumference is by transversal points — a method which, though others have indeed adopted it from us as the most certain and apt of all, and the easiest in execution, and liable to no uncertainty — is, for example, the one set out at the end of the aforesaid book on the Comet of the year [15]77 (as I likewise noted before). It is also explained more fully in Germany by those who have laid claim to it, among them that man of Wittich [Paul Wittich], who disclosed it among others at Kassel as I had shown it to him, and perhaps even marketed it for his own profit.

It must be noted, however, that when an observation of the Sun's altitude is made, it is most convenient — so that the boundary of the shadow may be determined more exactly upon the rule itself — to fit to the rule near the dioptra an oblong sight-vane in the form of a four-sided channel, made of some light material, lest by its weight it impede the rule and its sight-vanes. We leave, then, near the cylinder A — both above and below — a certain opening, in the manner of a rule, through which the Sun's rays passing on either side admit the shadow of the cylinder in four-sided form into the inner part of the lower sight-vane; and so, within that four-sided figure, the analogous figure of the shadow is more distinctly expressed. And so that on this account the opening of the channel may be more conveniently and distinctly looked into — just as we have grown accustomed to do in observations of the Sun as well — we make it so that the boundaries of light and shadow stand out more readily.

This instrument is fitted together and disjointed by means of certain firm screws A B C D L, in several places as well, marked here by letters — though they are not all shown. But its arc, together with its subtended chord B C, is not separated; rather they always remain conjoined, lest the arc remit anything of its exact circumference through the bending of its course. It has, moreover, a foot to which is fixed — when its altitudes are to be taken (as here) — that which is expressed by E G H, into which a motion is fitted below at the screw G by a little peg near D; and from there the lower screw, turned upon the screw G near the lower terminus of the divisions at C, indicates the side A B level with the horizon and aligned to the plumb-line.

There is also a point L, at which a fine orichalc thread is to be hung, midway between the center A and the terminus B on the circumference; so that it makes an isosceles triangle A B C. For it is known from the rudiments of geometry that

the semidiameter of the circle and the subtended chord of the sixth part of the circumference are equal to one another. And since the line C L falls at right angles upon the line A B, and is plumb, by the line C L being adjusted, it is necessary that, for the adaptation, this Zenith be taken to view; and that horizontal plane truly; so that nonetheless the instrument may be brought to as exact a disposition by altitudes as if we were to use a whole Quadrant. Its pedestal, or foot, is firmly compounded of solid wood in the form you see. Within, however, it is for the greater part hollow, lest by too great a weight it make the carriage burdensome. Nonetheless it has, where there is need, certain iron fittings accommodated here and there — by which it is the safer against bruising and damage.

Furthermore, there are present three oblong [fittings] of iron, propping it from the middle right up to the extremity of its foot, of which two are indicated by I H; the third lies at the rear part, which can likewise be applied and removed by its own screws. There are besides four steel screws, which fasten the whole instrument, of which three are marked by the letter H; the fourth, on the other side, is not seen. These, in order that the instrument may be rightly and firmly directed, afford convenience, while certain small metal plates set below keep the pavement from being unevenly pressed by the weight and point of the thing beneath; they are turned about until the observer has arranged the instrument conformably to the plane of some vertical circle, and that by a plumb-line hung from it, as he finds [needful].

Its use is this: when it is so handled, it serves for all altitudes, both of the luminaries and of the other wandering and fixed stars, exactly to within a third or fourth part of a minute — provided they do not exceed the sixth part of the heaven. Indeed, when it is fixed otherwise like a Quadrant — namely so that A C looks toward the Zenith — the remaining part can be had. But for altitudes alone it is thus apprehended; not, however, azimuths at the same time. Such a sextant is exceedingly well suited to determining the altitudes and distances of the stars to a hair's breadth, and it presents neither difficulty nor any uncertainty in this practical work, since it consists of few parts, and those (as I have said) firmly braced together among themselves — lest among the things to be observed anything be distracted beyond its due tenor. And this it does (as we both noted before, and now note again) so that it may be transported to other places too without difficulty, and without injury or inconvenient damage. This is to be striven for, so far as can be done, in certain instruments: that we be not the servants of places; for an Astronomer ought rather to be a κοσμοπολίτης [Greek: kosmopolitēs, "citizen of the world"] — a man devoted to the parts of Philosophy

— and everywhere to reckon as his own Fatherland, according as convenience or necessity brings.

Quadrans Muralis sive Tichonicus

QVADRANS MVRALIS SIVE TICHONICUS.

(The Mural Quadrant, or Tychonic Quadrant.)

Diagram. The celebrated engraved plate of the Mural Quadrant at Uraniborg. A great graduated quarter-circle (arc) is fixed against the wall at the right of the scene, sweeping from upper right down to the lower left; its scale is marked in degrees with engraved numerals (visible: 10, 20... 70, 80, 90 along the arc). At upper left of the arc's center the sight-aperture is set in the wall. The body of the plate is filled with a wall-painting (a picture within the picture) depicting Tycho Brahe's house and instruments on three levels, with Tycho himself seated at center pointing toward the sight-aperture. Below and around, attendants work: one at the quadrant reads off the scale, one tends a clock, one records observations at a table. Labelled / inscribed elements (positions as drawn):

- Cartouche (top center, within the painted scene): "EFFIGIES TYCHONIS BRAHE O. F. AEDIFICII ET INSTRVMENTORVM ASTRONOMICORVM STRVCTORIS A° DOMINI 1587 ÆTATIS SVÆ 40" — *"Portrait of Tycho Brahe, son of Otto, builder of the edifice and of the astronomical instruments, in the year of the Lord 1587, of his age 40."*
- M (upper left corner of the plate frame): corner label.
- P (upper right corner of the plate frame): corner label.
- R (left, upper): label on the painted scene's left margin.
- S (right of cartouche): label.
- N (right, on the upper wall niche): label on an instrument niche [?].
- C (upper right, at the top terminus of the arc): start of the graduated arc.
- The arc scale (down the right side): graduations numbered 10, 20, 30, 40, 50, 60, 70, 80, 90.
- F, E (right, near the arc with small numerals 10, 20 beside them): sub-graduation markers on the arc [?].
- D (right of Tycho, on the wall): label.
- T (center right, on the wall by the globe): label near a celestial globe [?].
- Y (center, on the wall): label.

- A (center, near Tycho's hand pointing at the aperture): the sight-aperture point.
- X (center right, lower): label on the lower wall.
- B (lower right, at the lower terminus of the arc): foot of the graduated arc.
- G (lower right, by the clocks): label near the clocks.
- I (lower right): label near the clock dials.
- L (lower right): label by the lower clock dial.
- K (lower center, on the cabinet face): label on the clock cabinet [?].
- H (lower right, on the kneeling assistant): the assistant reading the quadrant scale.
- O (bottom right corner): corner label.
- Q (bottom right, by the standing figure's foot): label.
- N (bottom left, by the seated recorder's table): label at the recording desk.

The great quadrant represented here by B D E C, called the Mural [Muralem] or Tychonic Quadrant [Tichonicum] from the wall to which it was fixed, we had constructed of solid brass [orichalcum], cast and very finely polished, five fingers in breadth and of the same thickness, and of such size in its circumference as the radius — that is, the semidiameter of the circle — required, namely nearly five cubits. Its degrees are therefore very large, so that even the individual minutes in them are subdivided into six small parts. And so it displays distinctly each tenth second [scrupula secunda], so that even half-minutes — that is, every fifth second — are not difficult to discern in them. All this is marked very finely by certain transversal points [puncta transversalia], in the manner we customarily use.

This quadrant is fixed to a wall, M P Q, which faces the meridian exactly with its plane. It is fastened with the firmest screws, so that by no force or violence it may be moved from its proper position, which has been prearranged so that it corresponds most precisely to the celestial meridian drawn from the horizon to the zenith — though [it lies] on the opposite side. On the other wall, L M N B, which is at right angles to the first and faces east and west exactly, at the upper point, where the center of the quadrant is, [there is] a certain brass cylinder, gilded so that it may not be exposed to the injuries of the air or contract any tarnish. This is shown beside the letter A, in a certain square opening [foramine quadrato] of the same wall, which can be opened and closed on the outside by a suitable little door [janicula], so that sighting [collimatio] may be made about the said cylinder from either side when it is needed; and this through the sights [pinnacidia], either D or E. For this quadrant has two of them, so that one may use whichever is convenient — according to whichever is more suitable for the

altitude being measured. And each of them is square in plane, to the size of one palm. The aforesaid cylinder also corresponds exactly to it in its diameter, so that through parallel slits [rimulas parallelas] applied to the sights themselves, sighting is made in all four positions, if both the altitude and the transit through the meridian are to be taken at once. Otherwise, if the altitude alone is desired, the observer who is depicted beside F completes the task through the upper and lower slit and the corresponding parts of the cylinder, and indicates the counted altitude to the other assistant, who sits at the table beside G with a lamp, to be written into the book of observations. And so that the time of observation and the very moment of transit through the meridian may be established together, a third assistant, marked at H, attends the clocks [horologia] I and K, [noting] when the observer at F gives the signal — and this moment of time too is written into the book by the man who sits beside G. The clocks of which I spoke are such that they indicate not only the individual minutes of the hours but also the seconds of these, with the greatest possible precision, and they imitate the uniformity of the celestial revolution. Although this is achieved with difficulty, nevertheless, with the requisite diligence applied, it can in some measure be obtained, and any error that may have crept in can be noticed and corrected. For that reason there must be at least two clocks of this kind, so that one may correct the other wherever there is need. We have four of this kind at hand, of which one — the largest — manages the whole business with three wheels [rotis], of which the larger, cast of solid and pure brass, has 1200 teeth [denticulos]. For it is two cubits in diameter; the rest may be judged from this. The remaining three clocks are smaller and need more wheels; the construction of all these we shall give, God willing, elsewhere [V. D. = volente Deo].

Whatever pictures [picturae] are seen within the circumference of the quadrant were added only for the sake of ornament, and so that the intervening space should not stand idle and empty. To explain these too briefly — although it bears less on the matter — will not be altogether inappropriate. Beneath the letter T is depicted my own portrait [effigies], sitting beside a table set for a meal, in a long flowing robe [talari veste], reclining myself a little, so that with the right hand he extends toward the cylinder, as if pointing, while with the other he places upon the table a book and certain other things, as if I were indicating to my students what is to be observed, and how it is to be put to use. This portrait was rendered with great skill by Tobias Gemperlin [Tobias Gemperle], an outstanding artist (whom I once took with me from Augsburg [Augusta Vindelicorum] into Denmark), and so fittingly that scarcely a more faithful one could be made. It is represented in equal form according to the stature and size of the whole body. Above the head, beside X, a certain gilded brass globe is formed, which, by means

of wheels skillfully fitted inside, turns of itself and imitates the daily motion, and also exhibits the contrary courses of the Sun and the Moon about the poles of the ecliptic. So that even the Moon turns itself according to its phases and illuminations, increasing or diminishing them; while the Sun, within the 24 hour-circles, besides its own proper motion about the axis of the equator, being carried round by the daily course, shows the individual hours of the day one by one, and also the time of its rising and setting, and its transit through the meridian on either side. This ingenious device [αὐτόματον [Greek: automaton, "self-moving thing"]] was invented by myself and constructed at my expense, in the year of our Lord 1590. To the most serene Prince, Lord Christian [Christianus], then King-Elect, my most clement Lord, when before

— some years, indeed, before, around the seventh year of his age, [and around] the fourteenth year of my own, he did not disdain to visit me clemently on the island of Hven [Insula Venusia, Uraniburgi], with — besides the rest of the courtly nobility — three foremost senators of the realm, who then presided over the government; and he accepted [the device] as a humble gift, which he preserves even now. The most serene King-Elect in turn graciously presented me with a golden chain [torque aurea], of the kind he was then accustomed to wear, beautifully wrought and adorned with his portrait. Above the globe itself, of which we just spoke, beside the letter V, a part of our library [Bibliotheca] is represented. At Y and Z hang two portraits, solidly fashioned within a round frame, of which one is of that most serene and powerful King of the Danes, Frederick II [Fridericus II], of most praiseworthy memory; the other of the most serene Queen Sophia [Sophia], his consort, most illustrious, who always pursued me and my studies with royal and clement favor. Further, the things that are seen in the inner picture — first, above, beside the numbers 1, 2, 3, 4 — are some of my instruments depicted here. Then, below this story [contignationem], the Museum [Musaeum] is shown. There, beside 5 and 8, are tables at which my students of astronomy used to sit, meanwhile to calculate or to do other things pertaining to this purpose. There were in the Museum itself four such tables. For I was always accustomed to support at least six or eight — sometimes ten or twelve — such students, summoned from wherever; besides boys and younger disciples of this kind. Within these tables there is seen, beside 6 and 7, behind a column set up in the middle of the round Museum, that greatest brass globe, six feet in diameter, which we shall afterwards exhibit and explain in its place. Finally, below all these, beside the numbers 9, 10, 11, is seen my chemical laboratory [laboratorium Chymicum], which was entirely subterranean and vaulted [crypticum]; in which were 16 furnaces of various kinds and forms, fitted out for chemical operations [Pyronomicas]. For I was intensely devoted to this study too, from my earliest

years, no less than to the astronomical, and I cultivated it with great diligence and at no small expense. Last, beside my feet, near the number 12, lies a certain hunting dog of ours, which was exceedingly faithful and clever. It is depicted in that form and size in which it was seen — a hieroglyph not so much of nobility as of cleverness and fidelity. And so you have the whole picture, so far as so small a form allowed it to be imitated, briefly set forth — which three different and excellent artists painted for me. My portrait was done by that Augsburg [Augustanus] painter of whom I spoke; the architectural parts [Architectonica], and the things comprised in them, by my architect Johannes de Embda Stenwichel [Hans van Steenwinckel]; while the things depicted above that, in the manner of a description of regions and mountains, where the Sun too is seen setting, were added by Johannes de Antwerpia [Hans van Antwerpen], royal painter of Kronborg [Coronaburgensis]. For each of the said three artists excelled the rest in that very thing which he had done. Finally, above, beside R S, is the inscription of the portrait and of the whole picture, just as you see.

The use of this great quadrant is in investigating most accurately the altitudes [sublimitates] of the stars, to within a sixth part of one minute, the sighting being made through some one of the sights — through the upper and lower slit, beside either edge of the cylinder, which is likewise analogous to these — and by counting the altitude itself on the outer surface of the quadrant, beside the position of the same sight. The moment of transit through the meridian can also be had at the same time from either side, both of the sights and of the cylinder, by means of the accurate clocks of which we spoke. But how, from a given altitude and the moment of time at which a star transits the meridian, its place is established with the motion of the Sun applied, is known to astronomers. I have relied very much on this quadrant in restoring the motion of the Sun from its meridian altitudes, the square shadow of the cylinder being let into the inner part of one of the sights, [and] receiving and comprehending that shadow exactly in a likewise square figure. Nevertheless I also employed other great quadrants as a check, so that a matter so subtle might be free from all suspicion of error.

QVADRANS VOLVBILIS AZIMUTHALIS.

[The Revolving Azimuthal Quadrant.]

Diagram. A full-page engraved plate showing the Revolving Azimuthal Quadrant [Quadrans Volubilis Azimuthalis]. The instrument is a large quarter-circle frame built up of an open lattice of crossing braces, mounted so it can revolve about a central vertical iron column resting on a pedestal. The quadrant arc, graduated

along its limb, runs across the figure; the whole stands within a circular walled crypt whose horizontal ring (the azimuth circle) is shown around the base. An ornamental flame-finial crowns the top of the structure.

Readable labels (positions approximate; the plate is finely engraved and several small letters are degraded):

Rim / arc:

- V (top, at the crowning flame-finial ornament): flame ornament / finial above the apex
- I, I, I (three small italic caps along the upper edge of the arc — one near the finial, one mid-arc, one near the right terminus): repeated marks on the rim
- f (upper-left of the arc): small italic point-letter
- P, R, E, A (descending the left limb of the arc; A at the broken/foreshortened bearing at the lower left): points on the left limb
- R, B, P (down the right limb of the arc; P lowest): points on the right limb

Lattice body:

- A (top-left bearing): the cylinder / sighting point
- N, T, M (read top-to-bottom at the small circular socket-dial cluster on the right-center of the lattice): socket-dial cluster
- R (lower junction where the lattice meets the rim): junction point
- [?] (P/Q, at the broken bearing, upper left of the lattice): lower broken-bearing letter, ambiguous between P and a smudged Q

Base rings / horizon circle and axis:

- T, T, T, T, T (recurring on the concentric base rings / horizon-circle bands, at least five distinct marks): consistent labelling of the ring members
- S with a small open circle (lower left, on the upper base ring): S followed by a degree/index mark, noted as printed
- E (top of the central vertical pillar/axis where it enters the lattice): axis point
- [?] (F/t, on the pillar/foot, right side): pillar-foot letter, ambiguous between a capital F and a tailed minuscule
- Graduated scale along the lower edge of the arc: a degree scale in 6° steps — 6, 12, 18, 24, 30 legible; higher values [?] (lost in the rim hatching)

The bulk of the peripheral labels were recovered at native resolution; two glyphs remain ambiguous letterform calls (P/Q broken-bearing letter, F/t pillar-foot letter) and the degree-scale values above 30 are not recoverable.

This revolving quadrant [Quadrantem Volubilem], which would not only investigate altitudes (like the sextant described before) but also reveal azimuths exactly into the bargain, we constructed in the form you see. It is four cubits from the center A to the circumference, and the circumference is subdivided so finely by transversal points that it displays a fourth part of one minute to the sighter [collimatori]. The eye being applied to the sight K, and the rule A K being moved until the star to be observed shines equally on the sides of the cylinder beside A, on this side and that — for then the rule, where the divisions cross beside K, exhibits the altitude sought. And the index Q, which extends into the azimuthal circumference through R, at the same time lays open the data of the azimuths. The frameworks [contignationes] that are seen within the area of the quadrant are for this reason arranged in such a manifold way, so that the limb may keep and preserve itself both in its plane and in the rest of its due conformation. And the limb itself, in which the divisions are, is everywhere covered with brass plates [orichalcicis lamminis]; while the remaining parts of the quadrant too are fortified, partly with steel, partly with brass mountings [incrustationibus], as need requires.

This quadrant is fixed firmly to a strong four-square iron column [columnae forti ferreae quadrilaterae], L M N, with which it also revolves most readily, into whatever part of the sky one pleases. For from this iron column, made rounded at the top, fitted firmly into a certain opening of dense ironwork [ferramenti densi] — which, crossing through the round wall, forms a little tower or crypt [turriculam sive cryptam] in which the instrument was kept — [the quadrant turns]; while below, where beside G the same column ends in a deep point of steel, it revolves likewise in a small opening pointed in the same way; and this on a certain little steel plate [laminula Chalybea], which can be pushed any way one needs by four little screws [cochleolis] set on the outside, until both plumb-lines [perpendicula] of the quadrant — beginning beside A and ending beside S — so direct both the plane of the quadrant and its back, however it is turned about, that it represents any vertical circle [verticalem] exactly when caught at rest. Once this has been done, and provision made carefully for the quadrant's position in the various and diverse regions of the world, and it has been secured with the requisite screws, there will be no need to attend long to the plumb-lines as to whether the quadrant has been moved from its requisite position. For that cannot happen unless by some great violence coming on unexpectedly; and then

too it can easily be restored in the manner described. For it rests so firmly on the round rock H — which, being solid, stands deep in the earth, immovable upon another stone foundation — and [on] the ironwork which, crossing over, projects above, of which I spoke as resting on the stable wall, that it does not allow the iron column, to which the quadrant is fixed, to waver at all in its opening, which is in the middle.

This round wall, exhibiting the periphery of a circle exactly (whose diameter is about six cubits, so that there may be sufficient space between the circumference of the quadrant and the concavity of the crypt, where the observer may conveniently walk about), has above it a certain circle, mechanically wrought, clothed with brass plates, on which it furnishes the minutes of azimuth for all [the points] of the whole horizon (to which they correspond by their own equilibrium); and at the same time the beginning of the azimuths, which depends on the meridian line, persists unmoved, [established] with such great care and subtlety in its investigation that it deceives the observer by not even one minute. The meridian line [Meridiei linea], by another and far more certain method than has hitherto been done by anyone, [was determined] by us from the pole-star [stella polari] itself — especially when on either side from the pole the greatest angle of horizontal removal is caused, and when the star then seems to remain as if in the same point of azimuth for a little while — by a reasoning found out [to be] infallible and expeditious. And this was worth the effort, since few things in astronomical observations can be brought to completion without the most accurate knowledge of the meridian line.

The manner of handling and observing with this instrument is as follows. Toward whatever star in the heavens is to be marked, [the instrument] is directed by revolving the plane of the quadrant, and by raising and lowering its rule with its sights, until through the slits of the sight, beside the eye of the one positioned, that star is first seen exactly on the upper edge of the cylinder by the upper [slit]; and then likewise the same is done by the lower slit, the lower edge being attended to. For thus the rule, where it cuts off the divisions beside K, lays open the altitude of the star sought most exactly. But if by the same operation we have a mind to know the azimuth too, let the quadrant be turned a little this way and that by its column, until the same star is seen at once through both lateral slits, beside the flatness of either side of the cylinder. For then the index Q in the horizontal circumference at once lays open the very azimuth. But since these two — on account of the continuous and swift motion of the heavens — are not easily discerned together and at once, it is better to fix the index Q at some certain

azimuth which the star is approaching, [and] to wait until, by that universal motion, it is carried down and [stands] in the same in-

EXPLANATION OF THE CONSTRUCTION AND USE

[continuation of the Revolving Azimuthal Quadrant description]

the altitude, by raising the sight-rule [regula] with its dioptra up or down; and this is managed with almost no trouble at all.

The use of this instrument is the same as that of the others, which are operated by means of altitudes and azimuths. It has, however, this advantage over the rest: that everything can be carried out by it without effort, both very exactly and reliably, so that one can attain to within a quarter of a minute. This was denied to the earlier instruments, both because of their small size and because their structure was not so neatly arranged or so easy to use. For this reason the astronomer should regard this design as most highly recommended to him. So that the observer may use the instrument more conveniently, both in observing and in counting off the readings, the steps marked by T rise all the way around, running roughly parallel with the quadrant itself, so that standing on the topmost step he can observe a star positioned near the horizon, while sitting near the lowest step he can observe one near the zenith, and likewise for those in between.

This instrument is governed, moreover, by means of its own little vaulted turret, skillfully built up from light boards, which below is attached to the horizontal wall outside the azimuthal circle, fixed to a round armilla [ring] of strong wood. This armilla has, set squarely within it at four points, certain small wheels [rotulae], by which the turret can be carried around the circumference of the horizon in any direction with the least trouble. It also has oblong windows, which the roof contains, likewise made of boards; these stand opposite one another, so that the turret can easily be directed toward whatever star is to be observed. These windows are closed when the observation is finished, so that the instrument may be safe from the injury of the air, of rains, and of winds. This must also be guarded against, in whatever way it can be done, with the other machines as well. For these cost a great deal, and are easily rendered liable to damage unless they are kept safe from violent shocks and from the defiling and corrupting effects of the elements.

A GREAT STEEL QUADRANT, ENCLOSED ALSO WITHIN A STEEL SQUARE, AND LIKEWISE AZIMUTHAL

[QVADRANS MAGNVS CHALIBEUS, IN QVADRATO ETIAM CHALIBEO compræhensus unaque Azimuthalis]

Diagram. An engraved plate showing the great steel quadrant set within a steel square, the whole mounted azimuthally on a revolving iron column inside a domed crypt. The quadrant arc runs as a graduated band from the upper region down toward the lower right; the square frame encloses it, with diagonal struts (the cross-ribs) crossing in an X-pattern to brace the assembly. Below, the iron column rises from a cylindrical stone base set in concentric rings (the crypt floor and azimuthal horizon circle). The vaulted dome arches across the top.

Readable labels (with their approximate positions on the plate):

- A (upper right corner of the square): corner of the quadrant/square
- B (upper left corner of the square): corner of the square
- C (right side, mid-lower): point on the quadrant arc / right side
- D (repeated around the crypt floor, lower corners and ring): markers on the crypt floor / surrounding ring
- E (lower right of frame): lower corner / strut junction
- F (left-center, on the descending rule): point on the sight-rule
- G (upper left interior): junction of the cross-ribs (with H, K, L, M, N, V)
- H (upper center interior): junction of the cross-ribs
- K (upper center, right of H): cross-rib junction
- L (upper right interior): cross-rib junction
- M (lower center interior): cross-rib junction
- N (lower center interior, left of M): cross-rib junction
- o (on the azimuth circle, lower left): lowercase azimuth-circle label (the "d o" series), NOT a bracing-rib node
- P (left, on the rule): point on the sight-rule (with Q) — pinnacidium and dioptra location
- Q (lower left, end of the extended rule): outer end of the sight-rule
- R (right side): index point on the azimuthal horizon (azimuth pointer)
- S (left side): index point on the azimuthal horizon (azimuth pointer)

- T (right side): point on the azimuthal horizon circle (T V W)
- V (upper-left interior, on the cross-rib just below K): lettered structural node of the internal cross-bracing
- W (left side): point on the azimuthal horizon circle (T V W)
- X (top center, at the dome): point at the top of the column / dome aperture
- Y (lower center, at the column head): pivot point of the revolving column
- Z (left foot of the steel square): capital at the left foot of the square frame, with a repeated lowercase "z z" along the lower base-rib
- a (across the top, repeated): points on the vaulted dome
- b (on the cylindrical base): the stone column-base
- d (repeated, lower region and rings): markers on the crypt floor and concentric rings

EXPLANATION OF THE CONSTRUCTION AND USE

This quadrant too is made entirely of solid steel, and is surrounded besides by a steel square. It accomplishes the same as the preceding instrument — indeed, still more delicately, since it somewhat exceeds it in size. For it measures nearly five cubits from the center to the circumference, over and above the square, which likewise consists of solid steel and encloses it. The quadrant itself, on the side where the divisions are, has been so skillfully overlaid with brass [orichalcum] that one would judge this brass to have been welded onto the iron — and that for this reason: that brass receives fine divisions more cleanly than steel does, however smoothly the steel is polished, nor is brass so liable to rust. The individual degrees are subdivided, moreover, not merely into single minutes, but each of those into six small parts, so that it represents seconds in tens [i.e. to a precision of 10 seconds] — by that special method which we have employed elsewhere.

The square that surrounds the quadrant is not overlaid with brass, because its use is of a rarer kind: the quadrant itself supplies with sufficient precision what is sought, so that the square would serve as a support and for more convenient revolution of the whole, even if it had no other use. Nevertheless this too has been divided most subtly upon the steel itself, again by our special method, so that each of its sides which bound the circumference of the quadrant — both the one that faces the horizon, D C, and the one that faces the zenith, B C — contains the last number of the canon of sines, of six ciphers [i.e. a sine-table value to six

digits]; and a rule drawn from the center across the whole plane demonstrates the altitude sought during observation, both on the quadrant and on the square. Here it does so by the equality of degrees; there [on the square] by the geometric method of sines and triangles — and nonetheless the result comes to the very same thing in both cases.

By the quadrant is understood A G M E; by the square, A B C D; by the rule, A P Q (which also has a sight-vane [pinnacidium] and dioptra at P, together with a cylinder near the center A), in the same manner as in the earlier instruments. The part of the rule P Q which projects beyond the quadrant can also be extended so far as to reach the corner of the square most remote from the center, or be shortened, as one pleases.

Furthermore, this instrument too has its own supports and framework in place of a base and for stability — fewer, however, than the preceding instrument, since the whole is metallic; and lest it be too greatly weighed down by the heft of these, even the ribs, marked by the letters G H N O and E K L M, crossing one another diagonally, are made of solid steel, and hold the whole square together with the enclosed quadrant firmly in its plane and proper arrangement. Moreover, this quadrant, together with its square, is fastened to exceedingly stout iron columns near X and Y, by which it too can be turned conveniently and most easily into all quarters of the heavens. For that column turns above in a round opening, which is in the middle of the ironwork indicated by the letter A [?], set crosswise [?] and firmly fixed in the wall of the crypt; and below, in an iron plate near Y, in the same way as described for the preceding instrument — so that here too, by means of screws arranged in four directions, the whole instrument can be properly fitted for use and held firmly in its revolution, lest it be drawn away from the required plane.

This plate, of which I spoke, with its screws, is fixed onto a round stone column indicated by B, which both supports the whole machine and itself stands deep on the iron set in another stone base. This very instrument also has, all around in the crypt wall, its own azimuthal horizon T V W, wholly overlaid with brass and set as it were in the middle of the wall, by which the observer standing on the upper step (for this instrument too has its fixed wooden steps, by which one must ascend and descend, as the observation requires, and as its size demands) can count off the azimuths, which are brought forth by indices on both sides, R and S. The diameter of this azimuthal horizon is so great that one may pass around it past the whole quadrant and the square itself, and within it; and so it measures nine cubits in its diameter.

By itself, then, this whole instrument is so firmly arranged and so secured with screws that, once correctly set in order, it need not easily fear that the force of human strength could move it from its place. So much for the construction and arrangement of this instrument — which is moreover protected entirely in its upper part by a roof, neatly worked, from the injury of the air. This roof too has its windows, which can be opened, and is turned about by little wheels carrying the roof into whatever quarters of the world the observation requires; and it is shut at the same time when the instrument is duly set, lest the wind drive its plumb-lines [perpendicula] from their natural course near D by violence, and furthermore, when there is no use for the instrument, to protect it from the injury of rains and winds. And these things concerning the roof were carried out for the earlier quadrant as well, as we said there.

Its use is the same as that of the former, in taking and counting off both altitudes and

azimuths, and insofar as these serve astronomy, as was indicated above. But here, since the quadrant with its adjoined square is not only wholly metallic but also exceeds the former in size, it shows both altitudes and azimuths still a little more exactly than that one does, so that even the sixth part of a minute [i.e. ten seconds] may be examined by it — where the very greatest precision is required, as is worthwhile in investigating the Sun's motion from its altitude and declination.

Let me add this too, by way of a colophon: that with these two quadrants — namely the preceding revolving one, and this steel one, likewise capable of being turned — together with one further called in to consultation, the very large brass mural or Tychonic quadrant (on which we afterward chiefly relied in tracking down the declinations of the Sun precisely, so that from it its place, and the whole of its course, might be restored without error), we also accomplished the same in delicately determining the declinations of the stars when they crossed the meridian, where the utmost precision was needed. For these three enormous instruments, duly arranged and adapted to use, yielded the altitude even down to tiny fractions of a minute, and all agreed together upon one and the same value everywhere. To these the sextants and other instruments, called in alongside, likewise bore witness.

SEMICIRCVLVS MAGNVS AZIMVTHALIS

[The Great Azimuthal Semicircle]

Diagram. A full-page engraved plate within a ruled border, showing the Great Azimuthal Semicircle mounted on a colonnade. The instrument is a large vertical semicircle (a hemispherical openwork frame of crossing arcs and rings) carrying a long sighting rule; it is supported on five pillars and crowned by three allegorical statues on a scrolled, foliate cresting at the top. Readable labels (positions as shown):

- a (upper left statue): allegorical figure on a pedestal (Geometry, per the description — holds a triangle/compass).
- b (upper right statue): allegorical figure on a pedestal (Arithmetic, per the description — holds tablet and chalk).
- B (top center of the frame, just below the central statue): apex of the vertical canal/channel of the plumb line.
- N (upper left of the frame): point on the rim of the semicircle.
- K (upper center): point on an inner arc/meridian ring.
- X (left, on the sighting rule): point on the rule near its upper bearing.
- I (center-right interior): inner fitting near the center.
- F (right interior): point on an inner ring.
- C (right end of the horizontal diameter): terminus C of diameter A C.
- A (left end of the horizontal diameter): terminus A of diameter A C, the center of the graduated division.
- G (left, near A): point on the diameter beam near A.
- D (center): center D, where the cross-irons intersect.
- M (center-left, on a small graduated arc): the small quadrant N O / scale near the center.
- Z (center, below D): central hub on the azimuthal ring.
- V (upper right, on the projecting rule end): the projecting tip V of the rule (rule Y A V).
- Y (lower left, at the far end of the rule): the counterweighted/handled end Y of the rule, with the two metal handgrips.
- T (twice, on the entablature above the two outer front pillars): bearing-blocks T.
- S (twice, near the T points): the small handles S (handle S T) for the leveling screws.

- R (near the pillar tops): the perpetual screws R.
- Q (central pillar): the central, middle pillar Q.
- P (the five pillar shafts): the supporting pillars P (four outer plus, with Q, five in all).

EXPLICATIO FABRICAE ET VSVS.

[Explanation of the Construction and Use]

We also conceived of yet another instrument, well suited for measuring altitudes together with azimuths at the same time; its form is shown by the preceding figure. We decided here to take a whole semicircle A B C in place of a quadrant, and nonetheless to place the center of the divisions at A, alongside the diameter A C — for in this way the individual degrees around the circumference of the semicircle come out twice as large as they would if the division were made from its own center. It is well known from the *Elements* of Euclid [Euclid] that an angle at the center of a circle is twice the angle drawn to that same point from the circumference, by the twentieth proposition of the third book, and by the others that bear on this point.

In the middle of this instrument, running from the center D up to the topmost apex B, there is a kind of oblong square channel. Within it is a plumb line, whose bob shows, in the opening at D, together with a length of brass wire, when the instrument is set up exactly vertical — so that it corresponds entirely to the plane of the vertical semicircle. The braced frames [contignationes] that are seen on either side in the form of an arc serve only as a stay, to hold this great semicircle firmly in its plane and circular course. It measures six cubits [sex cubitos] along the diameter A C.

The rule Y A V fitted to it is as long, from A to V, as the diameter of the semicircle; and at A Y it has a somewhat thicker projection, so that the rule may be raised and lowered in a kind of equilibrium. For this purpose, too, two handgrips of solid metal are added at Y. On its other side it has a plumb with a screw, near X, where it is held fast in the small quadrant N O, so that the rule may remain in a fixed position, wherever one wishes, until the altitude has been counted off in whatever part of the limb of this semicircle it then passes over.

This semicircular instrument is also covered on every side with sheets of brass, as the work requires, and at the top it has three figures, skillfully carved from solid wood and arranged on their pedestals there, as appears in the figure. This is

partly for the sake of ornament, and partly so that they may convey something by their representation in a hieroglyphic manner. For the topmost of all is the hieroglyph of Urania herself, of Astronomy. She is a maiden, lovely and beautiful, her face lifted to heaven and gazing at the stars; with her right hand she lifts up the celestial sphere of the revolutions, and with her left she takes hold of what the two lower figures, standing below her like handmaids, hold out to her. The color of her tunic is blue, interwoven with golden stars and with silver fringes.

The figure that stands below on the left side is the icon of Geometry. In her right hand she has a triangle, which she lifts toward Astronomy, and in the other a pair of compasses [Circinus] — by which she means to convey that, through measurement and mechanical construction, and also through the learned science of triangles, she serves Astronomy. She directs her eyes to the face of Urania and looks up to her with veneration. The color of her dress is somewhat dusky, interwoven with green, because she takes her name from things earthly. On her head she wears a laurel wreath, by which she shows that she always endures and is capable of inviolable truth.

On the other side, standing on the right, the maiden represents Arithmetic; she too, looking up to Astronomy, honors and serves her. In one hand she has chalk, in the other a tablet — signifying that she expresses numbers, which Astronomy needs in order to be made known; and that she resolves into discrete quantities what Geometry earlier supplied in continuous ones. She too has above, upon her head, a laurel wreath, since she is no less perpetual and truthful than Geometry. The color of her dress is white, suggesting paper or parchment, and is marked here and there with various ciphers. All of this is so that the instrument might be both adorned and, at the same time, made to indicate that Astronomy — the supreme and, as it were, the Queen of all the liberal arts — has chosen above all others these two, Geometry and Arithmetic, as her handmaids (though she does not neglect the others either).

Beneath this semicircle is the azimuthal horizon E F I G H, four cubits [quatuor cubitos] in diameter, consisting likewise of solid steel and aptly divided above into its degrees and the small fractions of them. In its middle it has two strong irons, intersecting one another crosswise at the center D, about which the whole instrument also turns, with iron supports fitted on the other side that keep it perpetually at right angles to the horizon. Beneath the iron horizon there are five pillars: the middle one, marked Q, stands in the very center below the center; the remaining four, marked with the letter P, carry the circumference, set apart equally and in fourfold division. All five, moreover, have at the top certain special

screws — called "perpetual" [perennes] and marked with the letter R. (This is to be understood of the others as well.) These, turned this way and that by the small handle S T, are thrust up or down until the azimuthal circle resting on them exactly matches the level of the horizon, and the standing semicircle matches the plane of some vertical. For these screws can raise or even lower a very great weight with the least effort, and they have many other conveniences as well in mechanical work.

EXPLICATIO FABRICAE ET VSVS.

[Explanation of the Construction and Use — continued]

The use of the instrument is sufficiently clear from its construction itself; and it is the same as with those things that are otherwise gathered by means of azimuths and altitudes — except that here, in the semicircle, the same is accomplished and counted that is done there in the azimuthal quadrants or rules, of which we shall treat later.

I will also point out this: that earlier, the steel quadrant enclosed in the steel square (which we discussed in the explanation of the immediately preceding figure) at first stood, in its lower part, upon a steel horizon, and was carried around within it — in the same manner as in another figure, although here, not having set it out, I have taken care to express it. Afterward it seemed more advisable, on the following ground (as the preceding figure shows), to take it out of this horizontal support and rotate it freely, because by its excessive weight (being, as was said, entirely of steel) it pressed too closely and heavily upon the horizon. For that reason it could only be turned around with the greatest difficulty, without the whole machine being shifted or set trembling. Nevertheless, its operation can be set up this way too; and then there is no need of any round wall all around to serve as the azimuthal circle, just as there is no need of the irons above and below, as in the preceding case. Perhaps we shall someday give an illustration of this arrangement together with its explanation — although the preceding method is by far more convenient and more reliable.

INSTRVMENTVM PARALLATICVM SIVE Regularum.

[The Parallactic Instrument, or Instrument of Rules]

Diagram. A full-page engraved plate within a ruled border, showing the parallactic instrument (Ptolemaic parallactic rules) mounted against a wall/pillar. A long graduated rule runs horizontally along the base; a second long graduated rule rises diagonally to the upper right, the two crossing to form a triangle; an upright graduated rule stands at the left on an ornamented vertical support, with a wall-mounted sighting box at the upper left. Readable labels (positions as shown):

- M (upper left): the wall-mounted sighting box / aperture fixture projecting from the wall on a bracket.
- A (left, on and around the upright support, appearing several times): points on the vertical rule and its base support.
- L (left, several times near the upright): bearings/fittings L on the vertical support.
- e (mid-diagram, at the crossing of the diagonal rule): point e on the diagonal rule near the joint.
- F (center, at the crossing, appearing twice — F over F): the hinge/joint F where the rules cross.
- E (lower center): point E on the horizontal base rule near the joint.
- K (lower left, near the joint): point K at the inner end of the base rule.
- B (lower center): point B on the horizontal base rule.
- C (lower right): the terminus C of the horizontal base rule (finial end).
- D (right): the terminus D of the diagonal rule (its lower bearing/finial).
- [?] (additional small letters along the graduated horizontal rule are too fine to resolve individually).

Account of the Construction and Use

I also wished to build this parallactic instrument — which others call the Ptolemaic rules [Regulae Ptolemaicae] — since it requires only a few parts, namely three rules, and gives a concise measure of the distances of stars from the zenith, and hence of their altitudes. I obtained one of this kind, however, made entirely of wooden material, which had once belonged to the incomparable Copernicus [Nicolaus Copernicus] — indeed, fashioned (as was said) by his own hands. It was given to me as a gift by Master Johann Hannow [Johann Hannow], canon of Warmia, in the very place where Copernicus had earlier lived. For in the year 1584 I had sent off one of my students — who served me in my astronomical exercises — to that region with a sextant after the model of the one explained

above in the third place, so that he might measure with the greatest exactness the elevation of the pole at Warmia by this means. For I suspected that close to three minutes were lacking in Copernicus's work concerning this observation, since the motion of the Sun and the greatest obliquity of the ecliptic, behaving otherwise than his own numbers supply, had alerted me to it. And experience itself confirmed that this was so. For from numerous observations made with my instrument — both of the fixed stars and of the Sun — the elevation of the pole there was found to be 54 degrees, 22 1/4 minutes, as I have demonstrated more fully in the first volume of my *Progymnasmata Astronomica*, page 34 and following. In that passage I show, by his own work redone, the causes of Copernicus's lapse in the motion of the Sun — not rightly handled by him. Now Copernicus had assumed the latitude of that place from his own observation to be 54 degrees, 19 1/2 minutes. There are therefore lacking in his figure, from the exact norm, 3 minutes less 3/4 — which I had indeed already gathered beforehand from his own data and the numbers built upon them concerning the solar motion. When that student of mine returned, he brought back not only the sextant I had entrusted to him, unharmed in every part, but also this other Copernican parallactic instrument, presented to me by that canon of whom I spoke. As soon as I saw it — wooden though it was, and unfit for use — it nonetheless so pleased me, for the sake of the memory of so great a craftsman by whom it was reported to have been made, that I could not refrain from composing a heroic poem on it, which is found in the first volume of our *Astronomical Letters* [*Epistolae Astronomicae*], page 195 and following. Moreover, a little later I had another of the same kind made in imitation of it, overlaid with sheets of brass [orichalcum], with a few things altered and added for the sake of more convenient use. Such is the one represented here.

There are three rules: DE, EF, and FD. The first of these, ED, which is raised toward the zenith, has above it another, joined alongside it at D, and revolving with it on a brass [pivot]. Both are of the same length, namely each of four cubits — except that the length of the upper one is taken from the letter D to F. For the part that projects beyond, namely FG, is added only so that it may contain and hold within itself the other, longer rule; for it is forked. The third rule, EH, which is longer, is likewise joined alongside the first at E (also revolving there), and has the length that is required when the two sides DE and EF enclose a right angle — that is, when the rule DF is so raised that it observes the equilibrium of the horizon. The dioptras [dioptrae], through which the sighting of the stars is done, are on this same rule beside H and I; and through the slits, parallel to the foremost pinnacidium [pinnacidium] above and below, they accomplish the task by a method devised by me. In the Copernican instrument there were, in place of

these, holes through which the stars were seen only with the greatest difficulty. And this further disadvantage is added: that the front hole set in the pinnacidium I had to be larger than the other, if the stars are to be conveniently seen through it. And since this is so, it necessarily occupies some part of one degree, at least an eighth or a tenth part. Moreover, it is not known, in the observing, whether the star is seen exactly in the center of its hole or not; and so a loss of some minutes can creep in. It is therefore astonishing how not only Copernicus, but also the ancients who used such dioptras, could attain anything certain by them, even if everything else were rightly arranged. The equal divisions on the longer rule are marked by transversal points [puncta transversalia], as is our custom; and they are so many that they fill out, in the required place, the last number of the canon of sines, of six ciphers — namely in that place which is matched to the first two rules, so that an equilateral triangle is formed. It must further be noted that the rule DK, which faces the zenith, has within it a certain cavity, in which a fine brass thread, hanging from the upper part, has below, beside K, a little lead weight, so that the thread which it supports within may not be moved by the wind. For little oblong doors as well have been added at this cavity, which can be opened and closed as need requires for the use of which I spoke. This — by a suitable mark added there — shows when the side DE faces the zenith most exactly. And this can be effected by the lower screws at A on the pedestal, which are turned by iron pins at L. For on these the three rules adhere to the columns CB, which stand upon the said pedestal C, in such a way that by round pegs they can be revolved this way and

this way. This convenience, as regards the supports, I added to this instrument; for in the Copernican one it was not present. I also added a little plume [plumula], which is beside G, ensuring that at any observed angle the rule AF rests still, until the numbering on the longer side has been completed. I applied also certain other things for the sake of more convenient use and handling — which I forbear to mention one by one, lest I should seem to exalt myself by correcting too much the inventions of my predecessors.

The use of this parallactic instrument is in taking the distances of stars from the zenith, just as Ptolemy [Ptolemy] very frequently did with the Moon, especially in order to determine its greatest latitude — although he did not attain that point sufficiently subtly nor universally, as is plain from those things which we restored, in the said volume of the *Progymnasmata*, chapter 1, in a certain appendix concerning the orbit of the Moon. There, from accurate observations, it is shown that the greatest latitude of the Moon, which occurs at the full moons, is not the same as that at the quarters, with a notable difference intervening —

amounting, indeed, to a third part of a degree, as may be seen there more fully through its attendant circumstances and occasions. Now the angle of distance from the zenith, FDE, can be had from the second canon, or also from the [canon] of sines, by means of the intervening parts FE. For in the triangle two equal sides are given, FD and ED; the third, FE, is counted off on the longer rule once the observation is completed. From this the angle FDE cannot be hidden, which measures the distance of the star from the zenith. And its complement to a quadrant is the altitude sought. These rules have this further convenience too: that they can be taken apart and folded up with ease, and transported to any place whatever. But — to say what is the truth — they do not, however carefully wrought, afford that precision and certainty so constantly as the aforesaid quadrants do. For straight rules retain a straight line by the rule [i.e. true] only with the greatest difficulty. And if they are longer, they bend down under their own weight; if shorter, they cannot deliver what their smallness promises.

ANOTHER PARALLACTIC INSTRUMENT, OR RULES SERVING FOR BOTH ALTITUDES AND AZIMUTHS

Diagram. A large engraved plate showing the second parallactic instrument set within a vaulted observatory chamber. The vaulted brick ceiling is shown at upper left, with two round latticed (cross-hatched) windows. The instrument consists of a long horizontal base rule resting on a circular azimuthal track, with two jointed sighting rules raised toward the zenith, a quarter-circle arc, a supporting strut frame, and a cord-and-pulley lifting mechanism. A plumb line with a weight hangs at lower left. The instrument turns on a substructure with a hand-crank screw.

Labeled elements (letters as engraved on the plate; several are small and partly obscured):

- A: the principal and fundamental rule, laid on the plane of the horizon (the lower long rule)
- B: junction point of the two minor rules AB and BC
- C: plate folio-key (signature letter) at the lower margin, paired with the EXPLI- catchword — NOT an instrument point
- D: the outermost end of the base rule, resting on the circular wall / azimuth circle
- E: dioptra/pinnacidium on rule AB (sighting slit toward the eye); printed mirror-reversed, beside A
- F: forward pinnacidium on the sighting rule [?]

- G: quadrant region (lower) [?]
- H: plume / catch beside the quadrants
- I: quadrant arc (the brass quadrants IHG enclosing the first rule)
- K: cord attachment point at the upper rule
- L: pulley/wheel point of the lifting cord (upper)
- M: left vane foot (foot of the left vane/counterweight assembly)
- N: cord/frame point on the support structure
- o: plumb fitting (lowercase, at the end of the plumb-line/pointer fitting on the left, below P)
- P: lower fulcrum point of the support (P V Z structure)
- Q: terminus of the plumb line [perpendiculum]
- R: over S on the central rotating sight-block (upper face)
- T: screw/crank point on the support X W
- V: screw (cochlea) point on the lower support
- X: the fulcrum / base-piece (X W) on which the whole instrument rests and revolves
- Y: upper alidade (mid-shaft of the long upper sighting-rule)

Account of the Construction and Use

Some years earlier I had built other rules in a certain tower, which fulfilled the same function by their own rotation when there was need. And this by a certain peculiar method — partly imitating the most ancient manner of Hipparchus [Hipparchus] (as it is reported), partly indeed by new additions devised by myself, destined for a more stable and more convenient use. The following figure represents their structure. In it, let AD be understood as the first and fundamental rule, arranged to the plane of the horizon and, as need requires, turned about; this equals eight and a half cubits in its length. It contains, moreover, on its upper surface the numbers of the canon of sines, divided by transversal points by my own method, of six ciphers, numbered twice over. To this are matched two other rules taken together — when, that is, they are applied to it — namely AB and BC, each of which contains 4 1/2 cubits in length. The former, AB, is joined at the beginning of the longer rule beside A, in such a way that it can be raised and lowered upon it, and at the same time draw along with it the latter, BC, attached to it beside B so as to revolve. In these two smaller rules there are no divisions; rather, the former, AB, alone has dioptras and pinnacidia through which the sighting is done, with slits in the lower pinnacidium beside the

eye at E, and in the further one at F, parallel on every side — so that the sighting may be done in this region both for altitudes and for azimuths, in whatever direction. All three of these rules are everywhere of brass, most finely smoothed and polished, having a quadrilateral form of suitable size, lest they be subject to bending. And so that the two upper ones may be raised and lowered more conveniently, there has been added to them a projecting support of some kind, indicated by LNOP, which also has below its own prop, represented by PVZ. Beside V, moreover, is a screw [cochlea], which directs that prop everywhere onto a circular plate at W in the substructure of the whole instrument's footing (of which later), lest it weigh itself down by its own weight. Now the projecting structure toward the zenith has this convenience, that it raises the topmost rules (as I said) and lets them down again at pleasure, and at the same time keeps them in their own plane, lest they be pulled apart this way and that. They are raised and lowered by means of a small cord KLNM, which above, beside L and N, has a little wheel in which it is aptly drawn; and the same is attached to the first rule beside K, where the underlying metal figuration, which turns on a round nail, is so far open within that the pinnacidium at F can be discerned from the eye beside the dioptra E on every side, with no obstacle. It has this advantage too: that by the plumb line, which ends at Q, it tests the position of the instrument — namely, whether AD faces the horizon exactly, and whether LNPO is orthogonal to it. Although this same thing may also be investigated by the plumb line BR. For it ought everywhere to fall midway between A and C.

Furthermore, so that the rules may be raised more conveniently, and rest in a fixed position (as one may wish), and also so that they may not waver this way and that, but everywhere keep the same plane with the lower and longer substance, however much they are moved up or down — there have been added to them on either side two quadrants IHG, within which the first rule is contained and moved, with a clinging plume placed beside H; and these quadrants are everywhere overlaid with sheets of brass. From the center A up to the circumference I it has nearly three cubits. Finally, where the divisions are to be counted off after the observation is completed, beside C in the place of the example, they are there indicated most acutely by a steel pointer, just as on either side beside C the plumes are of steel, which also assist in holding the rule BC lest it fall back by its own weight.

Besides this there is the fulcrum or footing (of which I spoke before), in which the whole instrument rests at one part — especially the rear — and revolves. By XW must be understood that in which, above beside T, there is a perpetual screw, like those of which I spoke before in the semicircular instrument, which — raised and

lowered by the handle at T — also directs this whole instrument duly, so that the lower and longest rule corresponds exactly to the plane of the horizon and agrees with it fully. Finally too, the outermost part D of the rule rests upon a circular wall, which is expressed by the letters Y. And it has beneath itself, in the same firm wall, an azimuthal circle of brass, suitably subdivided, and analogous to the surface of the horizon, and corresponding to the altitude which is that of the former footing. And it is twelve cubits in diameter.

The use of the whole instrument is this: that by its benefit it discloses both the altitudes (by the rules themselves, namely where it reaches the lowest point) and the azimuths themselves (where the extremity of the same, near the pointer at D, grazes and marks the azimuthal horizon). The altitudes are had thus: since both sides of the two rules AB and BC are equal, and the third, AC, is established according to the observation and numbering, the angle BAC cannot be unknown, exhibiting the altitude sought. The same is accomplished by another method, if there is counted off where the plumb line BR reaches the lower rule on its divisions, the beginning being made from A. For then there is given

EXPLICATIO FABRICAE ET VSVS.

there results a right triangle, of which one side is known from the construction and the other is determined by observation. The angle at A that was being sought therefore cannot remain unknown. As for the purpose served by altitudes and azimuths, this must be learned from practical astronomy, as I have already indicated.

Because this instrument exceeds the earlier rules in size and length, it displays everything more precisely and is more stable and better suited to use — especially for taking altitudes. In determining azimuths, by contrast, there is a certain difficulty arising from the sheer size and mass of the instrument. This can nevertheless be guarded against with some care, by setting the lower rule in place before the observation and fixing it immovable at some chosen azimuth toward which the star to be observed lies. Then, before the altitude is taken, attention should be given to the plumb lines [perpendicula], so that everything is properly arranged, both with respect to the leveling against the horizon and with respect to the vertical plane. For then both the altitude and the azimuth can be drawn from this instrument free of any appreciable error — no less than with the great quadrants explained above.

ARMILLÆ ZODIACALES.

[The Zodiacal Armillary]

Diagram. An engraved plate showing Tycho's large zodiacal armillary sphere, set within a ruled rectangular border beneath a small laurel-band head-piece and the title "ARMILLÆ ZODIACALES." The instrument is a nest of graduated brass rings (the meridian enclosing the others) mounted on a heavy four-legged iron pedestal that stands on a circular base ring, the whole shown resting on a stepped circular platform. Diagonal stay-rods brace the sphere down to the base. The readable labels:

- B (top of outer ring): upper point of the meridian, near the zenith / pole, where the plumb line BS is suspended
- C (upper right of outer ring): point on the meridian ring
- F (upper left and mid-left of outer ring): points on the meridian ring
- E (left of outer ring): point on the meridian ring [?]
- G (left, on outer ring): point on the meridian ring (meridian B G N H)
- N (lower part of meridian, implied) [?]
- H (lower center, below the sphere): lower point of the meridian ring
- M (right interior): point on the zodiacal/transverse ring
- R (upper interior): point on the latitude ring (K L R M)
- L (upper-left interior): point on the latitude ring
- Q (interior, several occurrences near center and lower interior): the pinnacidia (sight-vanes) on the zodiacal armilla; three are visible near the letters Q
- O (interior, near center): points on the transverse zodiacal ring (P O Q N)
- A (center): the central cylinder at the poles of the zodiac
- P (left interior): point on the transverse zodiacal ring
- K (lower-left interior): pole of the zodiac (canal I A K)
- I (interior): pole of the zodiac
- D (lower center, on the pedestal and below H): point on the iron pedestal frame (V T D W Y Z)
- T (lower center): point on the pedestal frame
- S (just below the sphere, at the pedestal head): location of the hole for the plumb bob of the perpendicular
- W, V, Y, Z (on the pedestal frame): points marking the solid-iron pedestal

- X, x (left and right, mid-height): the four iron stays (fulcra) bracing the pedestal
- d (four corners around the platform): the steps by which one ascends to observe
- a (base ring and feet, several occurrences): the iron base ring resting on the four stone columns / the columns themselves
- b (base ring, several occurrences): the four equidistant points on the lower iron circle of the pedestal
- y, z (lower interior, near the base): points on the lower pedestal frame [?]

[More than two labels carry uncertainty]

EXPLICATIO FABRICAE ET VSVS.

The preceding instruments are concerned chiefly with this: that altitudes and azimuths of the stars, whether separately or jointly, be observed in the heavens. But since the reduction of these to astronomical use requires for the most part the calculation of triangles — something not easy for everyone, and to certain people rather tedious as it demands effort — other machines have been devised by which the longitudes and latitudes of the stars (the two quantities chiefly sought) can be obtained with the least trouble and without troublesome calculation. Among these I find that two were chiefly in use among the ancients. One of them they called the armillary instrument, which was in use with Hipparchus [Hipparchus] and Ptolemy [Ptolemy], and so it took its name from them. The other is called the *torquetum*, an instrument devised (as I judge) by the Arabs or the Chaldeans and used by them. On flat circular surfaces it accomplishes the same thing the former does on armillae. This latter instrument I have not chosen to construct, because, if the machine is to have the required size, it weighs itself down by its own mass and becomes unwieldy for use. Nevertheless, if anyone wishes its construction, let him consult the *Astronomicum Caesareum* of Apianus [Peter Apian] near its end, or the booklet of Schöner [Johannes Schöner] on the same, prefixed to the *Observations* of Clement, that man of Regiomontanus [Regiomontanus], and of his pupil Walther [Bernhard Walther], a citizen of Nuremberg. There he will have his wish fulfilled.

The armillary instrument, however, I constructed long ago, in which I altered some of the things adopted by Hipparchus and Ptolemy for the sake of greater convenience. Its design you see here. This instrument is composed of at least four circular armillae (whereas our predecessors used five or six). Of these, the first, B G N H, represents the meridian. It must be arranged so as to correspond to the

heavenly bodies — that is, the poles of the equator at C and D in it are raised or lowered until they correspond exactly to the latitude of the place where the observation is made. This is tested by the plumb line BS, suspended above near the zenith, where the division of the meridian has the complement of the altitude of the pole, and is likewise removed by the same amount below from the other pole.

This meridian, moreover, contains within itself all the other armillae. Of these the first is C F I H, carrying transversely another, P O Q N, the zodiacal armilla, whose poles are at I and K. These are distant from the equinoctial points mentioned before by as much as is the difference of the poles of the ecliptic and the equator — that is, the maximum declination of the zodiac, which we have several times most exactly found to be at present 23 degrees, 31½ minutes, somewhat differently from our predecessors. Through the poles of this zodiac there passes a certain brass canal, I A K, having near the center A a cylinder; by these the convenience of whole armillae, used by the ancients, is supplied to us. Moreover, another armilla, serving for latitudes, revolves about the same poles of the zodiac but within it, indicated by K L R M. The zodiacal armilla itself has, in addition, its four slotted sight-vanes [pinnacidia], in the manner customary with us, of which three are seen near the letters Q; the fourth is hidden. The latitude armilla likewise has four such sight-vanes, near R, where the fourth is also covered. All the sight-vanes are of brass, just as all the armillae are clad in brass, and they have the divisions of the degrees made in the outer part by means of the transversal points [puncta transversalia] customary with us.

The meridian itself is made of solid steel, so that it may the more firmly support the inner armillae. It has three cubits in diameter; from this the size of the inner and adjoining ones may be inferred. Next, these armillae have a pedestal made of solid, dense iron, on which they wholly rest, indicated by the letters V T D W Y Z. Near S there is a hole for the plumb bob of the perpendicular. In the lower part of this pedestal, b, an iron circle passes through four equidistant places, which, above four stone columns fortified with little iron plates, can raise and lower the whole instrument so that all its armillae correspond exactly, in their planes and lines, to the same heavenly circles they represent. Moreover, four iron stays, X, are added, lest the pedestal — and with it the whole instrument — sway here and there because of its size. Steps, d, are added besides, by which one climbs up when needed, whether for observing or for counting. This instrument also requires a special little hut [curricula], whose roof can be removed by half during the observation, while the remaining part, as desired, can be turned about.

The use of these armillae, like that of the other Ptolemaic ones, is for taking the longitudes and latitudes of the stars. It requires two observers. One of them, having fixed some sight-vane on the zodiacal armilla at the place of the longitude of some fixed star, sights that same fixed star through both slits this way and that along the axis I K, and at the same time holds all the armillae so firmly that the plane of the ecliptic of the armillary corresponds in every way to the heavenly ecliptic. Meanwhile the other observer moves any one of the remaining sight-vanes in the zodiac, as...

the position of that star whose longitude he is seeking to find is most convenient, until through both slits, along the said axis, he sights that star exactly. For then the place of that sight-vane, counted on the zodiacal armilla, reveals the longitude sought. Next, for deducing the latitude, the latitude armilla must be brought to the same ecliptic longitude that has been found to belong to the star, and then one of its sight-vanes must presently be moved up or down until, near the cylinder at A, that star is sighted both above and below through each slit. For then that sight-vane itself will show the latitude that one wished to seek, to be counted from the ecliptic on the said latitude armilla, above or below, according as the latitude is southern or northern. And thus both the longitude and the latitude of the proposed star are easily made plain.

Although this armillary instrument is well suited for measuring the positions of the stars quickly and readily, and, constructed by us in this explained form, permits its armillae to sway out of their proper plane less than others do, nevertheless it is not so exactly safeguarded but that an error of one minute or another may here creep in — chiefly because the zodiacal armilla does not everywhere revolve in equilibrium, but by its own weight pulls itself and the others somewhat out of their proper planes, and that in various ways. And from this it has come about that we have more rarely used such armillae, especially when the highest precision is required. Rather, we have devised other, equatorial armillae, not liable to this fault. This fault can in no way be remedied in the larger zodiacal armillae, on account of the heavier weight of the rings; in the smaller ones, indeed, it is not so perceptible. But these, by their smallness, do not allow an observation exact to the minute.

THE EQUATORIAL ARMILLARY [ARMILLÆ AEQUATORIÆ]

Diagram. An engraved plate, set within a ruled rectangular frame, showing the equatorial armillary instrument. The upper portion shows the ring assembly: a large outer ring (the meridian ring) carries a graduated scale marked in tens; an oblique inner ring crosses it, and two further rings (the equator ring and the declination ring) intersect at the center. The graduations along the rings are numbered `10, 20, 30, 40, 50` and so on, repeating within each quadrant. Below the rings, an ornate scrolled pedestal in the form of the letter Y rests on a base; between the volutes of the pedestal are two framed allegorical figures with a suspended plumb bob between them, and below, an X-braced foot with leveling screws.

- B (top of outer ring): graduation point
- A (upper right of outer ring): graduation point
- C (upper left of outer ring): graduation point
- N (upper center, near ring crossing): label
- L (center-left, at ring intersection): label
- H (left, on inner ring): label
- M (right of center, on the declination ring assembly): label
- E (right, on the meridian ring at the pinnule-fitting): label
- F (left, on the meridian ring at the pinnule-fitting): label
- G (center, the cylinder at the common center of the rings): label
- K (center, near G): label
- O (lower left, on a ring): label
- D (lower center-left, on the meridian ring): label
- I (lower right, on a ring): label
- P (bottom center, below the rings on the pedestal axis): label
- S (lower left, on the base of the meridian ring): label
- R (lower right, on the base of the meridian ring): label
- Y (flanking the pedestal, both sides; also recurring on the base): structural-member labels for the Y-shaped pedestal
- The left cartouche frames a standing figure; the tablet above it reads `NCTG` [?] and the plinth below reads `1520` [?]
- The right cartouche frames a standing figure; the tablet above it reads `TEOD` [?] and the plinth below reads `1580`

- d (right of the central plumb-bob ornament): label
- V (center, on the suspended plumb-bob cartouche): label
- k, y (lower left of pedestal): labels
- h (left, on the pedestal scroll): label
- w (lower left and lower right, at the foot brackets, recurring): labels
- x (lower left and lower right, at the foot, recurring): labels
- b (lower left, on the X-brace): label
- g (center, on the X-brace): label
- z (lower center, at the foot brackets, recurring): labels
- a (right margin of frame): label

EXPLANATION OF THE CONSTRUCTION AND USE.

I therefore devised certain equatorial armillae [Armillas æquatorias], so disposed on either side, in equilibrium about the axis of the world's poles, that they could not be pulled out of true in any direction by their own weight, nor drawn away from the plane of the circles they represent, nor wrenched from their exact alignment. This was precisely what, for the reasons already stated, had been wanting in the instrument described earlier. Their form is as the accompanying figure shows.

There are only three rings, together with an axis, which measure both the equatorial distances of the stars and their declinations. The first and largest of them, AESF, contains and supports the rest and serves the office of a meridian. It is nearly 4 cubits in diameter; from this the dimensions of the inner rings are to be estimated, and to its plane they must be set and aligned.

Beside A, and in the opposite place at D, it carries an axle (as I said) — round and revolving together with the inner ring — which serves for measuring declinations. At its midpoint, which is also the center of all the rings, it supports a cylinder fixed orthogonally to it at G, of the same size in its diameter as the axis itself. This axis, which runs diametrically across the meridian, is to be raised together with the instrument until, by the divisions which severally bear minutes, the plumb line B reaches above and below the complement of the latitude of the place — so that it is set equidistant from the one plane of the meridian, or gently touching it on either side.

The inner ring, which I said serves for the declinations, is represented by N M O P. This ring can sometimes be united to the plane of the meridian, and again can be revolved within it into whatever positions the situation of the star to be observed requires. In two places, where it embraces the other ring set crosswise to it at right angles — the ring assigned to the equator — it carries on its exterior a plate indicating the very degrees and minutes of the equator on both sides, that is, both from the one part and from the other opposite part.

It also contains its pinnules [pinnacidia] in four places, or quadrants; of which here only two are shown, at M and O. In these the slits are parallel and equidistant from the cylinder at G, and likewise on the other side from the axis A D. Each quadrant, from the outer part of the ring nearest to the eye, is divided into 90 degrees, and each of these into 60 minutes, in the manner customary with us and often by transverse points indicated.

The other, transverse ring, which I said performs the office of the equator, is shown by H L K I. It too is firmly fastened in two opposite places to the meridian mentioned above at C, and to that diametral axis, and rests precisely upon it at right angles, and remains in it motionless and at rest. It too is, on its outer part, finely divided throughout into the degrees and minutes of the same circle. And it has four pinnules made just as on the former ring; of which two, I K, are shown here on one half of the circle; the remaining two are to be understood likewise on the other semicircle. All the pinnules are skillfully wrought of brass [Orichalcum].

The meridian itself is wholly of solid steel [chalybe], so as to be sufficient to support the remaining inner parts. But the two rings that pass crosswise within it (of which I have spoken) are coated with strong brass only on their hinder part, on which also the divisions are set out — for they are not everywhere encompassed with brass, so as to have less weight. They are nonetheless made of wooden battens forced into a round shape and many times coated with bitumen, so artfully composed that they do not consist of one solid piece of wood, but of several thinly planed into an oblong form, and with this precaution glued together: namely, that as one grain ran upward, the next was laid against it in the contrary direction — the part facing the top and the part facing the root being mutually transposed.

For experience has taught me that wooden material must be handled in this way for instruments, so that they are less liable to warping and change. Of all woods, the most serviceable here are the walnut tree, and that species of fir which the Germans call *Feuchtenholz* [German: *Feuchtenholz*, "fir-wood"] — provided they are sound and long seasoned. Afterward the rings, thus glued together from

various little wooden laminae and reduced to the proper form and size, are covered all around with a thin linen cloth or membrane glued onto them. They are then crusted over and colored with red lead [minium] mixed with white lead [cerussa] in linseed oil, so that they may be less affected by changes in the air.

Furthermore, these rings rest upon a pedestal, likewise of solid and strong wood of a peculiar form, which you see, made in the shape designated by the letter Y. Below, a square exists at each corner; here, at the corners, it has screws at X by which the whole instrument is directed into the required disposition, analogous to the celestial circles which it imitates. There also four iron braces are added toward its uppermost part, which lies next to the meridian, in the place of a prop and stronger support, lest the rings should waver this way and that; of which one is marked F b X, the other E A X. The remaining two are on the hinder part. In that place where this pedestal touches the meridian, it is round in the manner of a semicircle, so that the meridian resting upon it touches it on every part and leans firmly upon it.

For this same reason, four metal clasps are applied beside F S R E, within which the meridian can be embraced and turned about gently and firmly, until its axis corresponds to the axis of the world; and so it can be made firm and immovable. Below, in the sides of this pedestal, on either side there is a hole, by which the plumb at V hangs; on each side they are 4 [in number].

The figures, cleverly painted for the sake of ornament, represent the likenesses of [Ptolemy], [al-Battānī], and [Copernicus]; and also they represent my own. Of these, two — namely [Copernicus] and my own — are seen here beside [the pedestal]. The remaining two are concealed on the other side. The other things concerning this pedestal — such as the cross-beam beside g, and whatever other parts are applied for the sake of either strength or ornament — are sufficiently plain to one who examines the figure itself attentively.

The use of this instrument is in observing both the declinations of the stars (as I said) and their right ascensions. For when the ring D N M P is turned, together with its axis, toward the star to be marked, its pinnules are drawn and drawn back upon it until, beside the cylinder G, both above and below, the desired star is sighted in a parallel line; and then that pinnule, on the outer brass plate at the divisions, reveals the declination sought.

But on the other or transverse ring, let a suitable pinnule be drawn toward some star whose right ascension is already known from elsewhere; and let the other pinnule, whichever proves most convenient, be drawn by a second observer (for

there must be two so engaged) toward any other star, until it too is seen on both sides along the axis of the instrument. Afterward let the arc intercepted between the two pinnules be counted, which gives the difference of ascension of the stars; and this, added or subtracted as the procedure requires, makes known the previously unknown right ascension from the right ascension already known.

The same can be accomplished if the ring of declinations is fixed firmly in the place of a known right ascension, and a star is sighted alongside it as the known one; and meanwhile some one of the pinnules on the equatorial ring is drawn by another observer until the star whose right ascension is sought is sighted about the axis. For then that same pinnule, on the outer rim of the equator, exhibits the angle sought, without any addition or subtraction.

To what end the declinations and right ascensions of the stars, duly examined, are useful, and how easy is the derivation from these of both the longitude and the latitude of those same stars, is known to those who are versed in the astronomical exercise-ground [Astronomica Palæstra]; and we shall explain it compendiously elsewhere [V. D.: id compendiose explicabimus].

OTHER EQUATORIAL ARMILLAE [ARMILLÆ ALIÆ AEQUATORIÆ]

Diagram. An engraved plate, within a ruled rectangular frame, showing a second equatorial armillary — a fuller armillary sphere of several nested rings resting on an ornate pedestal that stands upon a checkered (tiled) floor. The outer ring carries a graduated scale numbered in tens around its circumference. Several inner rings (equator, ecliptic/declination rings, and a polar axis) intersect at the center. The pedestal is a scrolled support with allegorical ornament; below it a large inclined ring (an arctic-circle or supporting hoop) rises from three leveling feet set on the tiled pavement.

- B (top of outer ring): graduation point
- C (upper right of outer ring): label
- E (upper left of outer ring): label
- F (upper center, on an inner ring): label
- K (center-upper, at ring crossing): label
- Q (left of center, on an inner ring): label
- R (right of center, on an inner ring): label
- S (center, below K, at the inner ring intersection): label

- A (center, the cylinder/axis at the common center): label
- L (right of center, on a ring): label
- G (right, on the outer ring): label
- I (left, on a lower inner ring): label
- N (left of center, on a lower ring): label
- P (center-left, on a lower ring): label
- O (lower center, on a ring): label
- M (lower center, below O): label
- H (lower right, on the outer ring): label
- D (bottom-left of outer ring): label
- W (bottom-right of outer ring): label
- X (left, at the pedestal-ring fitting): label
- U (right, at the pedestal-ring fitting): label
- T (center, on the pedestal head below the sphere): label
- Y (flanking the lower brace, both sides; also at center of the floor ring): labels
- Z (lower left and lower right, at the leveling feet on the tiled floor, recurring): labels
- N (center, on the floor near the foot — second occurrence): label [?]
- AA (bottom center, on the front foot on the pavement): label

Explanation of the Construction and Use

I also took care to have another set of equatorial armillae built, of the same size, whose design you see here. The outer ring represents the meridian, as before. It too is wholly of steel [Chalybs], smoothed everywhere by the file, and divided across the whole circle by appropriate graduations, so that it contains each individual minute laid out separately. In all other respects — the plumb bob [perpendiculum], the poles, and the axis — it is to be understood just as in the earlier instruments.

The rings contained within this meridian ring are three, so that the whole instrument consists of four, one more than the preceding one. Apart from the rounded axle and the cylinder fixed to it — which conveniently serve in place of one ring — this instrument has, for that reason, three interior rings, the meridian excepted, because the equator is here made to revolve all the way round and does not stay at rest as it did in the earlier instrument. For this reason the equator

requires the ring I F G H to support it and to hold it square; and this ring too is of pure steel, so that it may be the stronger for that task, though it carries no graduated divisions.

The equator itself, of which I have spoken, marked by P S R, has its own divisions down to each individual minute, and these on both faces, as the discerning of distances along the equator, or even of momentary time intervals, requires. Sights [pinnacidia] are fitted to it at R and P; and there are more besides, not here drawn, which serve for observation. Their form is the same as in the preceding instrument, with the same arrangement and the same manner of subdividing the degrees. Another interior ring, designated by the letters N K L M, is suited, as before, for measuring declinations. It too lies within the equator, which it crosses at right angles, and it is revolvable, so that in the place where it touches the equator it may also indicate the equatorial points by means of suitable little plates set at S and M. It has its own sights as well, at Q and O, and two more not here drawn, which are likewise to be understood as present on the other side. Divisions are present on it too, finely matched to each quadrant.

All these rings within the meridian ring are everywhere overlaid with brass [Orichalcum] sheets, and that with such fineness and smoothing that you would say they had been cast whole out of solid brass. The axle too is of rounded brass, as are the sights themselves. The plumb bob R T hangs by a fine brass thread [filum], as has been my practice elsewhere. The rest, if I leave it out here, you will gather from inspection itself, just as in the earlier instruments.

These rings rest upon a support or pedestal made of solid steel, designated by X T V Y Z and the other letters set among them. Its upper part, a semicircle running from G W V, embraces the meridian itself together with the other rings; from the lower part it surrounds and sustains them continuously, with four clamps added, as in the earlier one. The remaining form of this pedestal is clear enough from the figure itself, where certain things have been added beyond mere utility, for the sake of strength and beauty; yet these too provide support. Everything, as I said, is of solid steel.

Set beneath all of these is a circle Z, thick and of iron, having screws at four points equidistant from one another. Beneath these, on a squared stone, are laid certain small iron fittings, so that by turning those screws the whole instrument may be directed to the position required for the rings to correspond to those of the heavens. By the same means, with the intervening plumb bob B T, which also unites the plane of the mechanical meridian with that of the celestial meridian, it sets the instrument in order according to the elevation of the pole; and thus it

renders all the interior rings analogous to the celestial circles they imitate. The whole machine is, in itself, quite sturdy and not easily subject to alteration, since it is everywhere of metal.

Its use is similar to the preceding one's, except that here the equator may be revolved at will within the meridian. Declinations are taken in the same way as before, in the declination ring, at its cylinder, by means of suitable sights set near the central point A. The equatorial distances [Aequatoriae Distantiae], or right ascensions, are taken in the cross equatorial ring as before, except that here this steel ring, which carries the others, can itself be of some use in this work. This further advantage accrues: when some star has been correctly sighted in its proper right ascension, then the point of the equator crossing the meridian indicates the right ascension of the midheaven. For this reason it also indicates the very instant of time, the place of the Sun being of course known exactly, as our Tables supply it. The equator can also be fixed in the meridian, and in this way, by a sight set in the same plane, the distance of any star from it can be taken, and from this the moment of time ascertained, as in the earlier instrument — which I omitted to mention before. Thus by these two armillary instruments both right ascensions and declinations, together with the most precise moments of time, can be measured conveniently — all of which are of the greatest use in astronomy.

If anyone wants more on the construction and use of this instrument, let him consult our first volume of the *Astronomical Progymnasmata* [Progymnasmata], chapter two, from its page 250 through to 252; though here, for the greater and chief part — besides certain other matters — what is needed has been sufficiently indicated.

I will add this too: that these rings can be taken apart by means of certain screws and assembled again. The same can be done with the steel pedestal or support itself, so that they may conveniently be carried elsewhere. This is a thing that ought to be contrived in all instruments, wherever it can be done without damage to them. For the astronomer must be a κοσμοπολίτην [Greek: kosmopolitēn, "citizen of the world"], so that if necessity and circumstance demand it, he is not so bound to any one region that he cannot freely and gladly migrate elsewhere and carry his instruments with him.

For very few are found who occupy themselves with these difficult disciplines and pursuits, and most rarely among statesmen — who wish to preside over the administration of the commonwealth — are there any to be found who delight intensely in these matters and who think it wise to foster and support them; but

far more numerous are those who, out of ignorance, turn away from them and judge them useless. The nursling of divine Astronomy ought not to be subject to such ignorant judgments, but should rise above and disregard them, and reckon nothing more valuable than to keep watch over these studies, and should let himself be moved by none of the importunities of others. And when men become too troublesome — whether statesmen or others — he should betake himself and his pursuits elsewhere: so that not even his native soil itself, which entices most men by its sweetness, should make him forgetful nor keep him bound to itself; rather it should teach him to set, before these earthly things, the heavenly and sublime cares that carry the marks of immortality. With a steadfast and persevering spirit let him always bear in mind, against every turn of events, that

> On every side the earth lies below, the sky lies open on every side above, and to the brave man any shore is a homeland.

The Greatest Equatorial Armillae, Consisting of One and a Half Circles

[ARMILLÆ AEQVATORIÆ MAXIMÆ, SESQVIALTERO CONSTANTES CIRCULO.]

Diagram. A large engraved plate showing the great equatorial armillae, consisting of a single full equatorial ring (a lattice-built great circle braced internally by crossing struts) plus a half-ring (semicircle), set within a masonry observatory enclosure with curved benches/steps and ornamented stone columns. The full ring is mounted on an inclined axis pointing to the celestial pole, its upper bearing carried by a column surmounted by a globe and a crowned figure (Atlas / the Moorish king of Mauretania per the text). A small celestial globe stands at lower left. The following labels are readable on the plate:

- A (upper left and upper right of the great ring): points on the outer equatorial ring near the upper axis bearing
- B (mid-upper, mid-lower of the ring): points on the ring / on the axis B
- F (left side of ring): mounting of the revolving rules / sights
- G (upper center, and lower right of ring): the cross-struts / framework (transtra) bracing the ring
- K (upper right): the bifurcated upper axis fork
- E (center): the central cylinder at the axis, where declination is read
- O (left, and mid): a sight position on the framework
- P (lower left column; right-side column): the stone columns supporting the semicircle, indicated by P

- Q (left, near O): the iron clamps holding the semicircle
- L (lower right): one of the columns admitting entry (with M)
- M (lower center-right): the other entry column / position
- T (multiple, on the curved steps lower center and right): the round inner steps used during observation
- V (lower left, lower right): points on the pedestal/steps
- N (left, lower right near the wall): the surrounding wall
- H (lower left, on the small globe): the stone globe surmounting the column
- C (lower left, near small globe): the upper iron support of the axis
- D (lower left): a point near the lower axis termination
- I (right): the effigy of Atlas / the Moorish king (Atlantis Mauritianae Regis effigies)

[Some peripheral letters on this crowded plate are small and partly obscured by hatching; positions for O, Q, V, and the duplicated A/B/G/T are given as best read.]

Explanation of the Construction and Use

Although the two equatorial armillary machines already depicted and explained earlier (which cost us a great deal) serve the purpose I mentioned quite exactly, I nonetheless afterward devised, and had constructed, certain others requiring fewer parts — namely, one with a single full revolving ring and another, a half-ring, at rest. By these two, everything I said about the earlier instruments is carried out not merely conveniently, but far more readily, and with none of the obstacle that the preceding ones present whenever the sighting must be made close to the equatorial ring itself. For in that case the front part of the ring obstructs the view — just as in the declination ring the sighting becomes difficult near the equator itself, not to mention certain other impediments.

These have, in addition, the further advantage that they can be made far larger. The degrees with their subdivisions can therefore be displayed still more distinctly, and they are nonetheless, by their own stability and revolution, well suited to use — and that more easily than the preceding instruments.

The form of these great and exceptionally compact armillae is the one we present here, so far as it has been possible to represent it in a plane. The letters A indicate the largest ring, which, fitted everywhere with brass sheets, has a diameter of 7 cubits [cubitos]. The degrees are accordingly so large that each single minute is subdivided into four parts. Its axis B, made of steel and everywhere exceedingly

round — yet hollow within, so as not to weigh it down — is three fingers in diameter. About its middle is fastened a rounded brass cylinder, around which, close by the axis, revolve on either side the two brass rules E F. Near F, at the surface of the ring, they carry sights for sighting through slits parallel to the cylinder itself.

The remaining spaces you see at the letters G are the cross-pieces or bracing framework [transtra sive contignationes] that hold and confine the whole ring, so that it may not be displaced from its roundness and plane on account of its great size. Lower down, at D, the axis ends in a rounded point, of squared steel, having a similarly pointed socket which, by means of screws applied on either side, can be pushed a little in whatever direction is wished. Upon this rests that round axis which holds and turns the whole ring. The iron member laid beneath this is fixed into a large and long stone column, 4 cubits, of which two stand below the ground on a firm foundation, while the remaining two, higher up, bear on their front side the effigy of the Moorish king Atlas, I, artfully carved in the same stone; with his crown he touches the stone globe H, set above the column for ornament's sake. The uppermost part of the axis, however, rests on the other, iron support at C; this is forked below at K, and passes into two branches, each of which is firmly fixed to a great rounded column of solid rock.

These columns stand so far apart from one another that they afford an entrance for going up to the instrument; they are indicated by M and L. Above, at C, is a screw which drives a transverse iron bar on which the axis there rests, so that it may correspond to the plane of the meridian. It is also adjusted by another means, both there and lower down at D, and is moved firmly until it answers most exactly to the axis of the world; and so it is fixed.

The other, semicircular ring is understood by the letters C [recte: the semicircle's letters]; it is supported, immovable, by eight little stone columns, indicated by P, at the plane of the equator, with as many iron clamps existing at Q, which hold and direct it until they mark out an exact semicircle about the middle of the axis and, moreover, incline it steadily according to the plane of the equator. It too is everywhere clad in brass, and is 9 cubits [cubitos] in diameter. It is therefore capable of even finer subdivisions than the ring itself. And on this account this semicircular member is, by two cubits, larger than the whole ring, so that one may pass conveniently between the two, as the work requires. By stone stairs outside the ring (which are not shown here) one ascends and descends along the lie of the ring, so that the observer's eye may be conveniently applied to it. Within, there are other, round stairs, indicated by the letters T, by which one

ascends or descends all around to the whole ring during observation, as the higher or lower position of the star to be noted requires.

By each of the letters N appears a wall which, encircling the whole instrument, forms a kind of little gallery and half-crypt enclosing this entire machine. Above it has a roof, which — in whatever direction one pleases — can afterward be opened and closed during observation, so that this precious machine may be safe from the injury of weather and rain.

Its use is as in the revolving circular ring: declinations are taken by moving the sights to F, and sighting the star on both sides past the cylinder E. For at E the declination sought is read off. This can be done in two ways — by means of either sight, namely — by revolving the ring so that the other part of the eye is brought to bear; and thus the declination of the same star is examined twice, which on both sides ought to come out the same. In the other, semicircular member, let its sights be moved

EXPLANATION OF ITS CONSTRUCTION AND USE

[continuation of the description of the Great Equatorial Armillae]

the sights [pinnacidia] near R, until the star to be observed is sighted through their slits on either side of the axis B. For then this very sight indicates the star's distance from the meridian — its equatorial distance, to be counted in that same semicircular armilla, whether toward the east or toward the west. From this the moment of time can be known with the utmost exactness from the known place of the star and of the Sun.

If, however, the right ascension [ascensio recta] of some star is to be found, one observer aims one of the sights at the star that has the known position, while a second observer aims the remaining sight likewise at another star whose right ascension is sought. In this way both stars are viewed through the slits of the sights at one and the same instant, around the same axis. The arc thus intercepted between the two sights then yields their difference in ascension [differentia ascensionalis], from which the right ascension sought is obtained — as has been shown in the preceding pages.

If anyone wants more about the construction and use of this very large instrument, let him consult the first book of our *Astronomical Letters* [*Epistolae Astronomicae*], page 246, and the two pages following. Some matters are treated there more fully, which here I have omitted for the sake of brevity. One can also,

if it is examined more attentively, grasp both the structure and the use more readily from the figure set beside it than from a long-winded tangle of words.

THE BIPARTITE ARC, SERVING FOR THE SMALLER DISTANCES OF THE STARS

[ARCVS BIPARTITVS MINORIBVS SIDERVM DISTANTIIS inserviens.]

Diagram. A full-page woodcut, beneath a foliate ornamental band, depicting the Bipartite Arc mounted on a pedestal. The instrument consists of a long sighting rule running diagonally from upper right down to a hub of scrollwork bracing at center, where two arcs of a divided limb sweep down to the lower left; the whole assembly rests on a turned vertical axis set into a heavy decorated wooden pedestal. Readable point-letters (positions approximate, as engraved):

- A, [?] (upper right): the transverse cross-piece at the head of the long rule, carrying the two cylinders. (A second label "B" was reported here but cannot be confirmed on the plate; downgraded to [?].)
- G, H (upper right, along the rule): points on the long rule near its upper end.
- D over C (upper left): a D at the top corner, with an open C on the graduated arc just below it — terminus points of the upper arc region near the divided limb.
- I (far left): outer terminus of the divided limb.
- L (center-left): central scrollwork region of the bracing.
- F (lower left, on the limb): a numbered/lettered division point on the lower arc.
- K (lower left): the initial point of the divisions on the lower arc.
- T, R, S, Q (center): the four corners of the round, thick fulcrum/pivot block at the middle of the rule.
- E (center): the square hole at the equilibrium point of the fulcrum.
- N, M (center, the semicircle): the semicircle along which the instrument is inclined sideways. (No "O" appears on the plate; the prior "O" here was a misread C.)
- P (center, lower): the round axle/socket point.
- V (below center): the canal/socket atop the pedestal.
- X, X, X (foot of the pedestal): the spreading feet of the base.

Full label inventory (verified): A, C, D(×2), E, F, G, H, I, K, L(×2), M, N, P, Q, R, S, T, V, X(×3). The arc is bipartite and graduated; the degree numeral marking the per-side division is not legible [numeral: ?].

EXPLANATION OF ITS CONSTRUCTION AND USE

Among the astronomical instruments that investigate the altitudes and azimuths of the stars in various ways, we have already treated those too which supply longitudes and latitudes, and beyond that declinations and right ascensions. It remains for us to take account also of those that examine the intervening distances [intercapedines] between bodies, and afterward to deal, in a mixed fashion, with certain other matters.

As regards the distances of the stars: in earlier years an astronomical radius [Radius Astronomicus] was devised by certain people which is sufficiently portable and suitable for carrying about, and which at the same time conducts itself well enough, in a theoretical way, in geometrical demonstrations. But in actual practice, and in its own working, it does not deliver what it promises in the approach — and this for various reasons, which I refrain from rehearsing here; perhaps elsewhere I shall deal sufficiently with these matters and with their correction, so far as can be done. Meanwhile I shall speak here of certain other devices, accommodated to use and offering the required certainty, which have been thought out by me and have hitherto been kept in use.

So, first, a certain instrument that furnishes the smaller distances — those within a twelfth part of the circle, that is, within one "sign" (as they call it). It is of this kind, as the figure set beside it shows.

First there is an oblong rule [Regula oblonga] beginning at F and ending at the transverse cross-piece B–A, whose length is 4 cubits. It has fixed in the said cross-piece two cylinders, near A and B, set at an equal distance from their common joint. From the centers of these cylinders, from the point F, there are drawn below two arcs, F–C and F–D, each of which — beyond the equal distance of half of A–B, counted from F on either side, which ought to have been represented by K–I (although the figure does not sufficiently suggest this) — the beginning of the numbering on the arc K–C or K–D presents, and each of them makes up fifteen degrees on either side. The remaining portion, by C–G and D–H, and what is interspersed around L and thereafter, has been represented and inserted for the sake of framing [contignatio] and support, and also for ornament.

This instrument rests upon a round and thick support [fulcrum], which is shown by T–R–S–Q. It has in the middle, where the equilibrium is, near E, a square hole, into which is set, on its own support, a small key, likewise square. The support is constructed thus: that near S and T, and also near Q and R, there are round iron plates, which turn upon an underlying round cylinder at least a span [spitamum] in diameter, supported by small feathers [plumulae] on four sides gripping it tightly, so that it stays put easily in any position. By this arrangement the instrument itself is turned only upward and downward. But if it has to be inclined or reclined to the side, that is done by carrying around the semicircle O–N–M and fastening the screw near N. For thus the whole instrument turns as one.

It can also, by means of the canal P–V — to which it stands fast on a round axle — be revolved this way and that into every quarter of the sky. This canal stands upon another pedestal, indicated by V and the letters X, in which it is also turned around in every direction together with the whole instrument, as need requires, so that it can be aimed into the plane of any stars whatever, as the manner of the observation requires. The inner axis of this same canal can also, together with the instrument itself, be raised on the underlying pedestal, and thus fixed unmoving as the use demands. For down within the quadrilateral form of the pedestal there descends a quadrilateral solid piece of wood as well, which can be carried up and let down and fixed wherever one pleases; and so the instrument can be raised or lowered as one, according as the stars whose interval is to be examined are higher or lower in the sky.

In the instrument itself, as regards the limbs where the divisions are, and also in the transverse piece and the cylinders, everything is of brass [Orichalcum]. The framing-pieces and supports are of ironwork skillfully wrought. The rest is of wood, cleverly assembled and protected with little metal plates where there is need, so that the whole instrument may be firm and fit for observations.

Its use is (as I have said) for conveniently measuring out the smaller distances; seeing that with the sextant (of which later), which moreover requires two observers, this cannot be aptly accomplished, on account of the conjunction of their heads, which demands a suitable space — although we have remedied this inconvenience by a certain other means as well, of which hereafter.

Now, so that the intervals of the stars which do not exceed a twelfth part of the circle may be marked off with this instrument: let one observer fix the sight near K or L, whichever is most convenient, and let the other draw the one that is not fixed along the further limb, until both have at the same time sighted the stars they are investigating around the cylinders B and A on either side — each

attending to the star at his own cylinder, on the same side. And the distance that was sought is to be counted on the lower limb, in transverse degrees and minutes, beside the appropriate sight. But if both have drawn theirs apart in either direction, a still greater interval can be counted in the same manner, provided it does not exceed the prescribed limit. The consequence, then, turns out to be this: that when both observers have arranged each sight near the very beginning of the divisions, which is near K and I, and so on both sides through the cylinders...

the front cylinders A–B have set up their collimation, in such a way that each looks to his own, disposed from the same side of the long rule — which then collineate the same star, provided they aim their gaze in parallel. And from this the certainty of the instrument can be tested, whether it is in good order or not.

And although the support or pedestal of this instrument is convenient enough and fitted to the required uses, there is nevertheless another arrangement, in a globular body (of which we shall speak later, in the exposition of the Sextants), which is still handier, and allows the instrument to be aimed more quickly into the plane of any stars whatever. Yet the variety in these things not only gives pleasure, but also has its own usefulness.

With this instrument I have chiefly examined the mutual distances of the stars in Cassiopeia, which are set out in the fourth chapter of our *Progymnasmata* [the *Astronomiae Instauratae Progymnasmata*], page 145 and the following; and I have compared these with the ones I had found earlier, while the new star — for whose sake those measurements were chiefly drawn — still lasted, and have found them to be in good order. If anyone has any instrument whatever with which he thinks he can investigate the distances of the stars, let him make the test on those same stars of Cassiopeia, whether he finds their interval to be the same as the one we noted in the cited place, down to the very minute, and indeed to the half of it. Otherwise let him know that the instrument he is using, and his manner of observing, are by no means correctly established.

THE ASTRONOMICAL TRIANGULAR SEXTANT, FOR MEASURING DISTANCES

Diagram. A full-page engraved plate of the Astronomical Triangular Sextant, shown mounted on a decorative pedestal and standing on a checkered (tiled) floor. The instrument is a triangular wooden framework forming a 60-degree arc (a sextant of a circle), heavily braced with internal struts for rigidity, and it rests

on a swiveling globe atop an ornate sculpted base. Two long straight rods brace the instrument down to the floor. A foliate ornament runs along the top of the title cartouche.

Labeled elements visible on the plate:

- A (left end of the arc, at the center / vertex region): the center of the sextant, carrying a round cylinder.
- B (within the frame, near A): together with A and C, bounds the framework body of the sextant.
- C (left, at the upper end of the graduated arc): with B, bounds the arc; the circumference C–B contains one sixth of a circle.
- D (on the graduated limb): the position of the movable ruler [regula] with its sight [pinnacidium].
- E (center of the frame, at a small medallion/wheel): the square aperture through which the instrument balances on its lower support.
- F (upper right of the frame): a second cylinder, equal to the one at A.
- G (near F): the second sight, added or removed as use requires. [?]
- K... K (across the pedestal base, left and right): marked positions on the pedestal where the column passes through and can be raised or lowered.
- I (on the supporting globe within the base): the globe encased in copper plating on which the sextant turns.
- O (lower right, at the foot of a bracing rod): the pointed iron tip of one of the two long rods resting on the pavement.
- M (lower left, at the foot of the other bracing rod): the pointed iron tip of the other rod.
- P (where the two bracing rods cross, near the lower frame): the point at which the two rods cross each other. [?]

Several further small letters on the inner struts and on the globe mounting are present but not clearly resolvable [?].

EXPLANATION OF THE CONSTRUCTION AND USE.

I now come to the explanation of the Astronomical Sextant, insofar as it is especially suited to investigating the angular distances between the heavenly stars. Since I had learned through the experience of many years that the Astronomical Radius [Radius Astronomicus] was by no means adequate for this task with the precision and certainty that is required, I was forced to devise almost from scratch certain sextants of various forms which would perform this

exactly, without any deception. Among these, the ones that reflect the construction you see here seemed to me the most reliable. I therefore had three of this kind made, differing only in a few small respects of their framing.

Its explanation is as follows. The framework enclosed within A, B, C represents the sextant itself with its bracing. Its center, at A, has a round cylinder. The circumference C–B, containing one sixth part of a circle, is removed from the center by four cubits along the sides A–C and A–B. To this, starting from the center itself, is fitted the ruler A–D with its sight [pinnacidium] beside D, which has slits parallel to the cylinder resting at A. It can be moved along the circumference this way and that, and fixed wherever desired.

It has another cylinder resting beside F, equal to the first one. To this is assigned another sight, added or removed beside G as use requires. The remaining intermediate parts are braced for the sake of rigidity, as appears here. Beside E there passes a four-sided aperture, made as it were at the balance-point of the whole instrument, so that by its means the sextant can be set upon its lower support and removed once an observation has been carried out. Its limb, along the circumference, which carries transversal divisions [divisiones transversales] — by which single minutes can be subdivided into quarters — is everywhere of brass [Orichalcum], just as are the cylinders and the sights. The remaining parts are indeed of wood, but so skillfully assembled and glued together from various pieces — as I have already indicated earlier in the explanation of the Armillae — that they cannot warp or be altered by changes in the air; this is further reinforced with linen [linteolum] and with an oily, wine-colored varnish.

For if all its parts were covered with thin metal plates, the instrument would be rendered unwieldy by excessive weight. Indeed, it would harm itself by its own heaviness in keeping to its proper plane. The pedestal, or support, on which it rests is constructed as follows. Beside I there is a certain globe, encrusted on all sides with thin copper plates and very accurately rounded, having in diameter a little more than two feet. Around it are four semicircular iron fittings, gripping a certain round iron ring [armilla ferrea] crosswise around the middle of the globe in eight places. All these stand off from the surface of the globe on the inside by as much as the thickness of one finger, and a little more. For in those places where these fittings hold that ring, there are eight iron screws, which drive a thin round plate — cut away all around into an oblong, so that it may have the usefulness of a spring — against the globe, so that it is firmly gripped by them, and however it is turned about, it remains steady.

These semicircular iron fittings also have on the inside such a spring, in which the globe rests usefully, [?] which is the ninth. On the outside, by means of a certain square iron, hollow within, it is fixed to a certain four-sided wooden column. This column passes down through the pedestal, which is seen around the letters K, so that the instrument can be raised and lowered in it, and fixed at a definite place as the convenience of observation requires. For in taking lower distances the column must be let down; in higher ones it must be raised, so that the sightings can be carried out without difficulty.

Furthermore, the sextant itself is set on top, beside the aperture E, as we have said, upon this globe which lies beneath it. Together with the globe it is most conveniently directed into the plane of any two stars whatsoever. And so that they may remain there more firmly, without wavering, until the observation has been completed, two long, rounded staves I–M and N–O have been added, having below, beside M and O, a pointed iron tip, so that they may rest more firmly on the pavement; and these cross each other above, beside P. One of the observers holds these in his hand there and steers them as he wishes.

The use of the instrument requires two observers. One of them, having applied his eye to the fixed sight beside C, sees through its slits whichever star he chooses, this way or that, around the cylinder A, and so holds the sextant motionless with the help of the little rods near P. With the plane of the sextant itself lying in the plane of the two stars whose mutual distance he wishes to measure — a task performed by the globe, on which it is turned about until both those stars are seen around its surface — the other observer then moves the ruler with its sight beside D, until he too, through the slits, sights the other star beside the cylinder A on his side. This must be attempted for so long until both observers, simultaneously and at one and the same moment, have sighted their own star. Then, at a signal given by word of mouth, they stop, and the circumference of the sextant, on its globe-shaped support, is drawn to the eye of each observer, so that he may conveniently count the interval C–D intercepted by the sight, which they were seeking.

EXPLANATION OF THE CONSTRUCTION AND USE. (continued)

Furthermore, so that smaller distances too may be conveniently taken with the same sextant, we have discovered this shortcut: that, a second cylinder having been placed beside F and a second sight beside G — these two being equally distant from A, E passing through the center to the middle of the circumference

— and with one observer looking through this sight at this cylinder, while the other applies the sight at D and the cylinder A, the distance of the stars must be reckoned from the middle of the circumference, beside the thirtieth degree, up to the sight D. And so, however small it may be, nothing prevents both observers from being able to obtain it.

If you desire more about this instrument, consult the first volume of my *Astronomical Progymnasmata* [*Progymnasmata*], page 247, and the three following pages. There you will find these matters more fully explained, since in the determination of the distances of the fixed stars — which I have there, in the second chapter, set out methodically [Canonice] and computed exactly to the celestial standard — its use has been very extensive. For concerning this instrument I can testify that it furnishes the intervals of the stars with such certainty and precision, and so quickly and easily, that nothing could be desired in it. This is plain even from the following: if anyone examines closely the distances of the stars indicated and applied to use in the aforementioned book, from page 195 up to page 263 — namely, how, with the declination of the stars also brought in, the whole compass of the circle, in its differences of right ascension, is most exactly comprehended and closed up by means of triangles constructed from them, where they are at the same time heaped together. This could not happen if any flaw were present. Therefore let the disciples of this art hold commended to themselves this method of observing the distances of the stars with such a sextant.

THE STEEL SEXTANT, FOR DISTANCES TO BE MEASURED BY A SINGLE OBSERVER

Diagram. A full-page engraved plate of the Steel Sextant [Sextans Chalybeus], designed so that distances can be measured by a single observer. The instrument is an open sextant arc supported on a turned, ornamented column rising from a four-armed cruciform base. A foliate ornament runs along the top of the title cartouche.

Labeled elements visible on the plate:

- A (lower left end of the arc): one terminal of the graduated sextant arc.
- B (upper right, at a sighting vane): the upper terminal carrying a sight.
- R (upper left, along the outer arc): a point on the curved outer rim of the arc.

- 9 (left, on the graduated arc near A): a graduation marking.
- G (center of the frame): the central hub / cylinder of the instrument.
- H (just below G): a point on the central mounting.
- I (left of center, on a cross-arm): a sight or cylinder position.
- K (lower left of center, at a weight/plumb): the plumb bob [perpendiculum] hanging from the hub.
- N (right of center): a point on the cross-arm.
- M (lower right end of a straight arm): the terminus of a straight radial arm.
- O (right, on the graduated arc): a graduation / sight position.
- L (lower right end of the outer arc): the lower terminal of the curved outer rim.
- S (lower left, on a curved bracing piece descending to the column): a point on the brace.
- P (on the upper column, with letters Q, T nearby): markings on the supporting column.
- Q (on the column below the swivel): a point on the column.
- T (lower on the column, above the base): a point on the column.
- V, X (left and right arms of the cruciform base): two of the four feet.
- Y, Z (front-left and front-right arms of the base): the other two feet.

EXPLICATIO FABRICAE ET VSVS [Explanation of Its Construction and Use]

I had also constructed, even earlier, another sextant made of solid steel [Chalybs], arranged so that a single observer, operating it by himself, can investigate the distances of the stars conveniently enough. This entire instrument can be taken apart by means of suitable screws — both the sextant itself and its support [fulcrum] — and then reassembled, so that, packed into a chest, it can be carried into other regions wherever there is need. This is just what I did, in fact, when I crossed through Germany about 24 years ago, in my youth.

Its construction is in any case clear from the figure itself. I shall add here, in summary form, the fuller explanation already given in the second book of our *Progymnasmata*, where the same instrument is depicted and described near the end. The sextant itself is represented by ABCD, and the point A is its center, whose arc BD is divided into sixty degrees and, further, each individual minute, by transversal lines in the manner familiar to us. The arms [Regulae] of the instrument, AB and BC, are fitted together at A around a round pin, so that they

can be opened out or drawn together like a pair of compasses. This is done by the screw marked with the letters GH, which, although it runs straight, nonetheless at the part where it meets the arm clings on all sides to movable nuts [matrices], so that it serves the motion of the instrument's arc no less well. It also has two handles marked with the letters IK, by which the instrument is grasped while sighting. B and C are the two sights [pinnacidia], near which the eye, directed at O close to the center, observes two stars at once. By means of the screw GH, widening or narrowing the angle BAC, where the arc BCD shows the distance sought — except that the parallax of the instrument arising from this must be subtracted. Yet I afterward devised a certain other means by which the sighting could be made along parallel lines, no less than with the other dioptras [dioptra] and sights; and so subtraction of the parallax is no longer needed. But because this arrangement of the dioptras is not represented here, I have resolved to explain it elsewhere. Here this same sextant is marked with these letters. Moreover, it has a pedestal in which, even by itself, the sextant can conveniently be directed onto any plane.

Each arm of this sextant, AB and AC, is about three cubits, by which the chord of its arc BD is subtended. And this whole sextant is finely wrought of solid steel, except that the sights are of brass [Orichalcum]; and it rests upon a certain support, so as to be more fit for use and more manageable during observation. The support and pedestal are made in this way: First, near the cross-footed base VXYZ, it stands firmly on the ground; next to which is a kind of hollow shank at T, so that a certain long screw may descend into it at Q, which is enclosed within P by another, called the perpetual [screw], whereby — as the work requires — the sextant itself is raised or lowered together. Each screw, moreover, is made of solid iron metal, just like the whole upper part of the support. The smooth iron AO is hollow within, around another oblong axle Q of that same screw, with a small knob appearing there in between, conspicuous, from which a certain point projects; to this is attached another long iron marked with the letters LM, which carries the sextant itself fixed around L, so that it can be extended along its whole length. And this knob is quadrilateral, and within is so contrived by an arrangement of little wheels [rotulae] that, when its screw is turned to N, then that point, through the inner little wheel and the oblong iron LM together with the whole sextant attached to it, tilts laterally this way and that toward the position of two stars. By means of the arc SR as well, on the smooth iron OH — concerning which it was said that the center, inserted by a special joint near S, is set at A — the sextant together with itself is raised or lowered, as the altitude or descent of the star requires, and is fastened as one wishes, in the same arc, by a screw on the other side near the adjoined 9. But all these things are better

grasped by the eye's inspection and by handling. With this instrument, which I had made many years ago, I investigated the distances of the stars; and its greatest use was in the observations of the comet of the year [15]77 [Comet of 1577]. Therefore, in the book which I composed luminously about that same comet, this sextant is described more fully, marked near the end (as I said). If anyone wishes, he may read more about it there, from page 459 to page 461.

Its **use** is for taking the distances of the stars within a sixth part of the circle, and that by a single observer alone, who — having applied his eye to the center A, and disposing the whole sextant by the screws of the support into the plane of those same stars — turns the screw GH in whatever direction; and so widens or narrows the angle BAC until both stars are sighted most exactly within the sights B and C. For then the division of the arc BD will show the distance that was sought. Its circumference had from the beginning not merely the common division, but also the Nonian [division] [Nonnianam]. But when I learned by experience itself that another, by means of transversal points, is far more convenient and accurate, I set these aside and afterward used that one; and I made the circumference of the sextant of brass, so that, unlike steel, it would not be liable to rust.

EXPLICATIO FABRICAE ET VSVS [Explanation of Its Construction and Use]

And I completed the distribution upon it in my customary manner, laid out crosswise by ten points within each sixth of the degrees in its parts. And so its use was more convenient. As to how far the distances of the stars pertain to astronomical matters, that should be sought elsewhere, both from our own writings and from those of other authors. For their usefulness extends very widely; and the observations of the said comet, recounted in the second chapter of the above-named book, which were made with this very sextant, supply examples of such cases, which in the following chapter are deduced by the reasonings of spherical triangles [Triangulorum Sphaericorum] to the end for which they were intended.

When Paul Wittich [Paulus Witichius], the distinguished mathematician of Breslau [Vratislaviensis], had seen this sextant with me in the year 1580, and when he afterward disclosed it to the most illustrious Prince William the First [Gulielmus I] of Hesse [Hassia], etc., the Landgrave of most praiseworthy memory, at Kassel [Cassellis], the latter — through his ingenious maker of automata — soon had such an instrument made, with certain things altered, of

which either Wittich remembered well enough, or as seemed otherwise good to those men. For in place of the screw G they fitted a chain, by which the angle of the instrument is widened or contracted. They kept the same form of division which Wittich had learned from me. Afterward others too imitated this structure; and some arrogated the invention to themselves, and it has turned out so with very many other things of mine. But it is an excellent confirmation of this instrument that the distances taken with it at Kassel agree, to the whole minute itself and to its half, with those which we carried out in Denmark [Dania] with our sextants — as is clear from the first volume of our *Astronomical Letters* [*Epistolae Astronomicae*].

ALIVD INSTRVMENTVM SIMILE PRIORI, PRO distantiis [Another Instrument, Similar to the Preceding, for Distances]

Diagram. A triangular distance-sextant viewed flat. Two long straight arms descend from the upper corners and meet at a point at the bottom, where the central pivot-housing sits; the graduated arc spans the two upper ends. A long straight crossbar passes horizontally across the middle, and a shorter graduated inner arc lies below it.

- B (upper left corner): brass sight at the left end of the graduated arc
- C (upper right corner): brass sight at the right end of the graduated arc
- K (just below C, at right): outer terminal / handle fitting at the right arm's top
- The graduated arc (running B → C across the top) bears the scale numerals **5, 10, 15, 20, 25, 30**, each subdivided
- D (left of center, on the left arm): position of the screw-fitting on the crossbar
- E (right end of the horizontal crossbar): terminus of the long crossbar
- F (just below D, at left): a hook/knob handle below the screw-fitting
- M (center, where the crossbar crosses the right arm): junction of the crossbar with the arm
- G (on the inner arc, left): point where the inner arc GLH is fixed to the left arm
- L (on the inner arc, where it crosses the right arm): point at which the inner arc passes the other arm
- H (lower right, free end of the inner arc): the trailing end of the inner circumference

- A (in the diamond cartouche at the bottom apex): the center of the instrument, with a small "o" marking the central point
- I (just below A, at the very bottom): the eye-position / lower pivot point below the center A

EXPLICATIO FABRICAE ET VSVS [Explanation of Its Construction and Use]

Now I had already earlier prepared a similar instrument, when in my adolescence I stayed for some time at Augsburg [Augusta Vindelicorum] in upper Germany — one made, however, only of wooden material and lacking a support, which for all its lightness was nonetheless manageable enough in other respects. But on leaving there I left it behind, as a gift, to that most kindly patron of these studies, Paul Hainzel [Paulus Hainzelius], consul of that most distinguished republic, of excellent memory. And when, after I had returned to my homeland, that new and exceedingly wonderful star [the *nova* of 1572] had soon shone forth from the heavens, I had another instrument of this kind made for myself, to measure its distances from the neighboring stars of Cassiopeia [Cassiopea]. Its construction you may see here.

The arc on which the divisions are placed is understood by BC. And this is at least the twelfth part of one circle, that is, 30 degrees — because for the smaller distances, such as these were, of which we have spoken, this was sufficient; nor would it be heavy or troublesome by reason of its length. Nonetheless, others place even larger arcs, applied to the same instrument, whether wider or shorter, as one pleases. The arms AB and AC, joined at the center A and there revolvable upon one another, and holding the circumference itself between them at B and C, have a length of 4 cubits, a width of three fingers [digiti], and a thickness of two. For they are quadrilateral, made of well-seasoned walnut [Juglans] wood, which is least liable, beyond the rest, to change from the quality of the air. But where the arms are coupled around the center A, they are secured with a metal pin, and also through the hole and the whole framework by little brass plates. The arc itself is solidly metallic — yet not too thick or wide, lest it do harm by its weight — while it is thus guarded against the alteration to which wooden material is subject. The sights at B and C are likewise of brass, and so adapted that their inner side corresponds exactly to the inner surface of the arms too; and on the other side, below, there is a screw by which the movable sight is fastened, once the observation is made, until the count on the limb [limbus] has been taken.

There is also another oblong screw near DE, by whose aid the angle of the instrument BAC is contracted and relaxed, as the distance to be measured requires. And although this screw runs straight, it can nonetheless suffice for the circular motion that takes place around DE above the center A — since, on the other side, where it has its nuts [matrices], it presents them revolvable on little round pegs, just as we explained in the preceding instrument as well. Moreover, within this screw, toward the center, still closer to the eye, there is a certain circumference GLH, fixed to the prior arm near G and passing by the other near L, whose office is to hold both arms in their plane, lest by reason of their length they pull apart somewhat. The angle of the instrument can also be fastened on this same arc, on its rear part. And it stands away from the center about a third part of the length of the arms, so that, conveniently applied there, it may be governed by the other hand, and the motion of the arms there may be steadied. It has, besides, two handles on the other side, which could not be represented here. I did not at that time construct any pedestal for it; but since the instrument was not too heavy, it could, mounted upon some cross-support fixed firmly below, be turned without much difficulty into any plane of the stars and held there until the observation was completed.

Its **use** is just as in the preceding one: the eye applied to I, the handle F turned about, and the screw DE turned along with it so that the angle of the instrument BAC is contracted or dilated, until both stars, whose distances we are seeking, are discerned exactly and centrally within the sights B and C. For then the arc, intercepted there between the sights and the arms, renders the observer master of his wish. And since the center of vision cannot be applied to the center of the instrument — with respect to which the divisions proceed — being prevented by the solid part that runs from A to I, it is therefore necessary that the distances, measured with the eye set eccentrically [Excentrice] and counted on the arc, be greater than the true ones that belong to the sky itself.

So that this inconvenience might be remedied, I had constructed a certain table [Tabella], and noted it on the other part of the instrument, so that it might always be at hand — showing, namely, how much, for each individual degree of the observation made, had to be subtracted as parallax, so that the true interval, consonant with the sky itself, might result — exactly the same as would come from the center of the instrument if the center of vision were united to it. And by what method this table was constructed, according to the inductions of plane triangles [Triangulorum planorum], is demonstrated by us in the *Progymnasmata of the Restoration of Astronomy* [*Progymnasmata Instaurationis Astronomicae*], in our first volume, page 342, in the fourth chapter of the same; which otherwise,

from page 335 to 343, exhibits a luminous description of this instrument. To which I refer the reader who is eager to learn more about this.

EXPLICATIO FABRICAE ET VSVS. [Explanation of the construction and use]

(Continuation of the description of the preceding distance-sextant.)

I leave aside. A little further on, in the same place, the reader will also find the distances of the new star [of 1572] from the nearer stars of Cassiopeia and certain others, and likewise the distances of fixed stars from one another, all measured most exactly with this same instrument and put to use. For at that time I had no other tool suited to this task ready at hand—having only just returned home from my travels in Germany, and being then occupied with chemical [Pyronomicis, i.e. "fire-working," alchemical] pursuits rather than astronomical ones.

Now this instrument is not so excellent as those I devised in several later years and had built, at great labor and expense, and which I afterward set aside as obsolete. Nevertheless, such as it is—since it is not without its usefulness—I have decided to depict and describe it here along with the rest, so as to take account of those who lack the means to construct such elaborate and costly instruments. Content with this one and the like, they will examine the intervals between the stars more correctly and precisely than has hitherto been done with the astronomical radius [Radium Astronomicum], provided only that they duly and readily guard against the parallax I have mentioned.

INSTRVMENTVM EIVSDEM VT ALTITVDIBVS CAPIENDI INserviat dispositio. [The arrangement by which the same instrument may serve for taking altitudes]

Diagram. A large engraved plate showing the distance-sextant mounted for altitude observation inside a vaulted observing room. The sextant's graduated arc is set at the upper left, leaning against a brick wall with an arched (vaulted) recess; the long ruler-arms (the sextant's radii and cross-rule) descend toward the right, where the instrument rests on a turned column-pillar standing on a

checkered tile floor. A plumb-line with bob hangs at the center. Readable labels and graduations:

- Graduated arc (upper left, along the limb): **40 · 45 · 50 · 55** (degree graduations of the limb)
- **N** (top, apex of the plumb-line suspension at the upper end of the arc)
- **E** (mid-right, on the chain/cross-rule)
- **H** (right, on a small curved fitting / arc segment)
- **M**, **L** (center, along the main ruler near its mid-length)
- **K** (right of center, near the joint of the rules)
- **R** (left, where the lower ruler meets the wall)
- **B** (lower left, foot of the base-ruler A B against the wall)
- **P**, **O**, **Q** (along the lower base-ruler near center, with the small arc P Q)
- **G** (center, on the lower ruler)
- **T** (lower right, on the base-ruler over the column)
- **V**, **X** (lower right, at/below the column capital — the fulcrum support VX)
- **D**, **F** (center, at the plumb-line and bob)
- **1** (far right end of the lower ruler) [?]
- A small numeral near the bob (a "5"-like mark) [?]

Several of the smaller peripheral letters (around the joints near K and the lower base) are faint; the principal labels listed above are legible.

EXPLICATIO FABRICAE ET VSVS. [Explanation of the construction and use]

This instrument, especially if it takes a sextant of a circle's circumference, is also not unsuitable for investigating the altitudes of the stars—provided it is arranged as the figure here set alongside shows. By this very method I, at that time, when that new star of the year [15]72 and the following year was being observed, determined its least altitude, when it was on the meridian below the Pole. For its greatest altitude, when it was approaching the zenith, could not be measured in the same way, since in our latitude [Horizonte] that wonderful star, when above the Pole on the meridian, stood not far from the zenith; and so its altitude could not be encompassed within a sixth part of the circle—as I have set out, on this and similar matters, in the book and chapter cited above.

The method by which I conducted the observation, also made plain in that same place, was as follows. This sextant, as regards its lower ruler **A B**, was set up in a certain high window above a wall **R**, in such a way that it corresponded exactly to the celestial meridian, which is required for the observation. There was a certain support, marked by the letters **V X**, placed beneath it; and at its rear part, toward the center near **T**, its height was such that the ruler **A B** itself agreed exactly with the equilibrium of the horizon. I tested this in the following way: I directed the instrument's arc **K N**, with its rules, to the plane of the meridian, and at the end, where there is 60. The degrees terminate next to **N**. There I hung the plumb-line marked by **N S**, and the fundamental ruler **A B**, by means of certain wedges placed between **T** and **V X**, I raised or lowered as needed; and so I adjusted the whole instrument until the brass thread **N O S**, from which the plummet hangs near **S**, touched exactly the midpoint between the sextant's center at **A** and the periphery at the division **O**.

For it then is clear that the instrument's ruler, or base, **A B**, is exactly equidistant from the horizon. Since, by the Elements of Geometry, the sextant of a circle constitutes from the center an isosceles triangle (as is demonstrated in the fourth book of Euclid, Proposition 15) by the points **R N A** and the line of the ruler **R A**: and since the perpendicular descending from **N**, which faces the zenith, bisects the base **R A**, it necessarily follows that it makes right angles—as appears from Proposition 12 of Book 1 [of Euclid] and from those immediately preceding. Therefore, since the perpendicular **N S** is always directed toward the zenith, and is united to **N O**, the ruler **R A** must be entirely orthogonal to that same perpendicular; and so it stands in equilibrium with the horizon, from which the vertex on all sides is distant by a quadrant of the circle, which makes a right angle.

With everything thus arranged as accurately and methodically as could be, I watched until the new star, in its declining course, came to be on the meridian by the motion of the whole [heavens]. Then, through another sight [pinnacidium] aligned analogously to the former, near **C**, set close to the center near **R**—which could be removed if necessity required—[I made the observation]. For in its forward part a certain slit had been made, parallel (with respect to the lower part and the center) to the upper edge of the former sight, through which, while observing, by means of the long screw [cochlea] **O E**, the angle of the instrument was varied, until I aligned the new star in the upper edge of the sight at **C** exactly, with half its disc seen and the other half hidden, so far as any keenness of sight allowed me to discern. For at that time I had not yet devised the slits parallel to

either side of the former sight, by whose benefit the center of a star is noted most exactly.

In this way, then, by the arc intercepted between the two sights **B C**, I found the star's least altitude above the horizon, such as I have reported in the place of the previously cited book. But since the ruler **B A**, and indeed the whole sextant, could so easily be displaced from the horizon's equilibrium during the observation—if the supports on which the instrument rested gave way, by the driven wedges, somewhat to this side or that—therefore, alongside a small line at **O**, set in the middle of the lower ruler, which the instrument's plumb-line, properly positioned, ought to strike by its contact, certain divisions had been fitted on both sides on a small arc **P Q** described about the center **N**, so that, for the quantity of one degree in the diameter of such a circle, minutes were distributed on either side—to be subtracted on the forward side **O P**, but added on the rear side **O Q**, according as the plumb-line showed some inclination from equilibrium one way or the other. And in this way, the altitude found by the arc **B C** having been observed and the observation completed, and the plumb-line inspected again, I verified it, and (where this seemed necessary) limited it more accurately.

But although the matter would be handled more exactly if the sighting were made through two parallel slits set close to the eye next to the forward sight, nevertheless, even doing it as I have just described, what was sought came out precisely enough—especially where the experiment can repeatedly be made on the same star, as in the case of that new star, which perpetually, as long as it lasted, kept the same altitude on the meridian, changed only imperceptibly. What has been said here, by way of this example, holds equally for measuring the altitudes of other stars as well, [provided they are] not exceeding a sixth part of the circle—

EXPLICATIO FABRICAE ET VSVS. [Explanation of the construction and use]

—is to be understood; and that not only when they are on the meridian, but also in any other vertical circle, the plane of the instrument being directed into the plane of that same circle, and everything else likewise arranged, as was indicated before.

The use of this instrument also for determining altitudes is thus clear from what has been said—although (to say what is the case) by means of those quadrants, especially the larger ones, of which I have already made mention, the same thing can be accomplished with less trouble and still more precisely. But since such instruments, being very costly, are not available to everyone, this one, of which we now treat, or some similar one, may be used—just as we earlier advised in the matter of taking distances with the same.

The careful investigator must beware, however, of those instruments, and of any arrangement of them, that easily waver or are liable in any way to be drawn into error. For the matter turns upon the smallest things, from which the greatest conclusions are drawn—lest we lose our labor and oil [oleum], as the saying goes. This is what happens to most of the more recent astronomers. Would that one were not permitted to suspect the same of those most ancient ones, as regards exactness of precision! Surely a more exact method of establishing an astronomy answering precisely to the standard [ad amussim] for all ages would be granted. Yet in this, so far as the observations and findings of our predecessors will allow, we have labored—and, God the Supreme willing, we shall labor—that, with all errors purged, the whole may be restored to its integrity.

The Greatest Quadrant, of the Kind We Once Built near Augsburg

[QVADRANS MAXIMVS QVALEM OLIM PROPE AUGUSTAM VINDELICORUM EXSTRUXIMUS.]

Diagram. A woodcut showing the great quadrant built near Augsburg. The instrument has a fan-shaped (quadrant) frame at the top, its triangular field filled with a lattice of square open panels (an open timber framework of crossing beams), with the graduated arc (limb) running along the curved lower edge. The arc is numbered along its scale. The quadrant is mounted on a stout central column rising from a square, partly cut-away subterranean masonry structure set into a grassy bank, with handles (manubria) projecting from the column for turning the whole instrument about its vertical axis. Foliage and plants surround the base.

- (top apex of quadrant frame): two ring/eyelet fittings at the suspension point
- C (left end of the graduated arc): terminus of the limb

- D (right end of the graduated arc): terminus of the limb
- (along the curved arc): scale numbered 10, 20, 30, 40, 50, 60, 70, 80 [reading along the limb]
- H (on the column, upper): bearing collar / fitting on the central column
- I (projecting right from the column): one of the turning handles [manubrium]
- O (projecting left): turning handle [manubrium]
- Q (projecting left, lower): turning handle [manubrium]
- N (on the masonry structure, right): point on the subterranean structure
- P (right of the masonry): corner of the substructure
- R (upper left, on the bank): point on the surrounding ground [label faint]
- S (left face of the masonry): point on the substructure
- T (within the cut-away substructure): point on the interior framing
- K (at the foot of the column, within the substructure): the steel pivot-point [not clearly visible at this resolution — see description]

An Account of Its Construction and Use

[EXPLICATIO FABRICAE ET VSVS.]

That ingenious quadrant, which twenty-six years ago I had built in the garden of Master Paul Hainzel [Paul Hainzel], at his country estate half a mile from Augsburg [Augsburg], I am pleased to include here as well, both the figure itself and an explanation of it — even though it no longer exists, but was destroyed five years after its construction. Nevertheless, if anyone should wish to have a similar one built, so as to have a model to imitate, I think it will be worth my effort to add this description.

The quadrant is represented here by the points A, C, P, together with its intervening framework. It was made entirely of oak timber that had been seasoned for many years, and its sides and cross-framing were on the scale of great beams. In its radius — that is, from the center to the circumference — it measured at least 14 cubits. Along the limb, that is the circumference, where the divisions were, it was overlaid with plates of brass [orichalcum]. The intervening framework was assembled from cross-beams, planed smooth and arranged for this purpose: to hold the whole quadrant together more firmly, and to combine it into its proper, true dimensions and a single flat plane.

The division of its circumference itself was only of the customary form. For I had not yet at that time devised the other, more convenient method that I afterward used on other instruments. None the less, the individual degrees could be subdivided not only into single minutes, but each minute into six small parts, so that it yielded even individual tens of seconds distinctly. The sights [pinnacidia] were on the other side of the quadrant, D E, where the observer would station himself, next to D. Of these, the one nearest the eye had in its middle a small hole, through which the stars were aligned along the diametral line at E. But if the Sun was to be observed, another sight was used, pierced in the forward position next to E, which through a round hole admitted the Sun's light within a circle proportioned to its size, from the inner part of the lower sight — an oblong tube being especially employed, so that the Sun's light would be less dissipated in the air and discerned more exactly within the limits of that circle. Furthermore, next to its center A there hung a fine brass [orichalcum] thread, which could support a lead weight of several pounds at the hole H, so that the thread would not easily be moved by the wind. For the thread itself indicated the sought altitude along the line of the divisions as exactly as could be.

This quadrant machine was attached to a thick and sturdy oak column about its center at A, by means of a strong rounded iron pin, fastened behind at G. Two brackets, fitted a little above the hole where the plumb-line's lead weight was, also supported the limb itself. And this too served a purpose: so that, when the whole quadrant was raised or lowered as the observation required, it would clamp and hold it tightly against the column itself, lest it should fall back by its own weight before the counting of the observation had been completed. The column itself, in its lower part, was secured and made to turn within a certain subterranean structure, X Y S P K, in such a way that — being pointed at its lowest part, and shod with steel at K in an underlying socket of the same shape — it could be turned about with the greatest ease, an upper, cone-shaped, rounded socket enclosing it on every side at H [recte: at the column bearing H, not A], so that it should not waver this way and that, but rather both the column itself and the quadrant attached to it should everywhere turn through all the planes of the verticals. The turning I speak of was done by means of the handles Q, O, I, N; and the quadrant, unmoved by its own weight, stood in whatever plane was needed. The whole of that part which is seen below the handles was vaulted [crypticum], firmly fitted together, and supported with stones both beneath and on every side, so that it might the more firmly bear the whole machine standing above, and, lest it be pulled apart this way and that, hold it fast. For the machine itself stood in the open air, and was therefore exposed to the winds and the injuries of the

weather. Nevertheless it was covered, especially around its circumference, lest the limb of the divisions should suffer any harm.

Its use was only in measuring most accurately the altitudes both of the Sun and of the rest of the planets, so that they could be noted down to within a sixth part of a minute — provided one applied the requisite care in sighting. Our predecessors scarcely ever attained to such precision, although we ourselves afterward achieved the same with smaller instruments too, made by another, more compact method. When an altitude was to be taken, the observer would apply his eye next to the sight at D, and through the other, forward sight he would scan for the heavenly body, raising or lowering the whole quadrant until this could be accomplished. But if the altitudes were lower [closer to the horizon], ladders were needed, by which the observer would climb up; then, the machine being left unmoved, the altitude

sought was indicated along the plumb-line's thread on the circumference. And let this suffice as to the construction and use of the instrument.

If anyone requires fuller details about the particulars, he will find them in the first volume of our *Progymnasmata*, from page 353 through 359. For there the altitudes of the new star [the nova of 1572], and also of certain other stars, recorded by means of this same machine by the aforementioned Master Paul Hainzel, Consul, for my sake, and afterward communicated to me, are reported on the following pages of that work. From these their precision can be evident to the discerning reader — a precision which agreed excellently with those measurements I afterward made in Denmark with other instruments. And it were to be wished that this remarkable machine had been preserved there longer and put to use, or at least that another had been built in its place. But since men attend far more to earthly things than to heavenly ones, they are accustomed to neglect such matters — perhaps to greater loss than they themselves readily perceive.

The Greatest Steel Quadrant, Enclosed in a Square, and Standing upon a Steel Azimuthal Horizon

[QVADRANS MAXIMVS CHALIBEVS QVADRATO INCLVSVS, ET HORIZONTI AZIMVTHALI CHALYBEO INSISTENS.]

Diagram. An engraved plate showing the great steel quadrant set within a square steel frame and standing upon a steel azimuthal horizon-circle. The square frame stands upright, with the graduated quadrant arc running diagonally within it (from the upper region down to the lower right). A long diagonal radius/alidade crosses the frame. Below, a large horizontal graduated circle (the azimuthal horizon) is supported on several short pillars (each marked X) standing on the floor of a domed chamber; a vaulted arch spans the top of the scene. To the right hang a plumb-bob and a circular latticed object; at left is another circular latticed window.

- F (upper left of the square frame): upper-left corner fitting of the frame
- G (upper right of the square frame): upper-right corner fitting
- D (right side, below G): point on the right upright of the frame
- M (within the frame, left of center): point on the framework / radius
- N (center-upper): point near the central axis at the top
- O (right of N): point on the graduated arc
- K (center, on the axis above the horizon-circle): the central vertical axis / pivot
- L (on the horizon-circle, left of center): graduation point on the azimuth circle
- R (on the horizon-circle, right of L): graduation point
- A (on the horizon-circle, right): point where the alidade meets the azimuth circle
- B (on the horizon-circle, left): point on the azimuth circle
- H (far right, lower): handle / fitting at the end of the projecting arm
- V (right, on the hanging latticed disc): the plumb-bob assembly / hanging sight
- W (below V): the lead weight (plumb) of the hanging assembly
- Z (left and right, on the pillar capitals): markings on the supporting structure
- X (on each of the supporting pillars): the columns supporting the azimuthal horizon-circle (several, each marked X)

EXPLANATION OF ITS CONSTRUCTION AND USE

I have already presented the quadrant described above among the instruments illustrated under number 7, but there it was arranged on a different principle: it was so set up that within the mural crypt it could be revolved in a strong steel

ring looking toward the zenith and nadir, while at the same time, within the circumference of the crypt's wall, it had a fixed azimuthal armilla. As I have sufficiently both depicted and explained there, together with the other requisites pertaining to it. But since at that point I promised to show, in its proper place, the other arrangement of it that I had used from the beginning, you have that arrangement here, which will now be briefly explained.

A B C D is the quadrant itself, described from center A and enclosed by the square A E F G. Its rule A C I extends downward to the handle H, near which is a sight [pinnacidium], having small slits parallel to the upper one at C. From C it is lengthened upward, at I, so that it can touch the square at every point. To it, above, near I, certain brass threads [fila Orichalcica] have been added in place of a support, so that the index always remains in a straight line. The parts seen from the rear, A L M N O, indicate an iron support holding the entire quadrant orthogonally over the horizontal base set beneath it. For near A it is joined to the azimuthal horizon — which in the manner of a socket has beneath it a small leaded screw [cochleola plumata] — so that by means of the handle that is at the rear, it can be carried around in the azimuthal circle itself to whatever position one wishes. The azimuthal circle of which I speak is represented by the letters P Q R S. By X are indicated the five strong columns supporting the whole machine; at their tops, near Y and Z, are certain screws, called the "perennial" ones [perennes], with their own revolving handles as well, which set the azimuthal circle level with the horizon and direct the whole quadrant into a vertical plane, as the plumb lines marked at V and W require. The rest is clear from the account already given at the place cited above, where this same quadrant was arranged in another and somewhat more convenient way. It did not therefore seem worthwhile to repeat more by way of explanation in this place, lest I tediously cook over again the same things said before. But so that the space below might nonetheless be filled, as before, a hexameter poem has been added, which the noble and learned young man Franciscus Gansneb Tengnagel [Frans Gansneb Tengnagel] — who for some time was a member of my household and the companion of my migration from Denmark — composed extempore so that it might be appended here.

Diagram. The figure of the great steel quadrant in its square frame is described in the prose above (the plate itself stands on the facing page of the opening). The lettered elements named in the text:

- A: the center of the quadrant, from which the arc is described; also the point joined to the azimuthal horizon

- B C D: the arc and corners of the quadrant A B C D
- A E F G: the square enclosing the quadrant
- A C I: the rule (alidade), extending downward to the handle and upward to I
- H: the handle, near the lower sight
- C: the upper sight with slits [pinnacidium]
- I: upper end of the rule, where the brass support-threads are fitted
- A L M N O: the iron support at the rear, holding the quadrant upright over the base
- P Q R S: the azimuthal circle
- X: the five strong columns bearing the whole machine
- Y, Z: the "perennial" screws with revolving handles, at the tops of the columns
- V, W: the plumb lines marking the vertical

[The poem of Franciscus Gansneb Tengnagel]

[The following is a Latin hexameter poem in italic; rendered into English prose. The Latin is heavily abbreviated and worn in places; uncertain readings marked.]

Yield, you humble Arts, and give way with your idle care; for Urania alone has raised her divine head above all the Muses, by as much as the heavenly bodies surpass the Earth, as much as the kindly light overcomes the darkness. And God himself gave to man a face so sublime — that he might gaze upon the stars, that he might lift his eyes upward and contemplate the heavens — and laid down the law by which the wandering stars are made subject. Happy, then, are those for whom these things are an inspired devotion, while others seek wealth and chase after honors, hunting for pleasures and luxury and any kind of amusement; engaged in these, they drag out a worthless life, stupidly, like cattle [niertum [?]]. Alas, into what does blind ignorance drive these men headlong — men to whose hearts no lofty thing is dear? But you, whose noble mind burns with the fire of a heavenly seed: rise up, eager, into the ethereal retreats!

Come now, Timochares [Timocharis], Ptolemy, Copernicus — although you trusted too much in deceptive instruments — let it be seen whether it is permitted for small men to climb the lofty tower by steps, or to reach the heavens with a pole; whether the inmost recesses of the star-bearing World [Mundus] may rightly lie open. Had your care not labored over these things in vain long ago, it would now be granted to reckon the stars better by your numbers. But you, whose mind borders on the gods — draw near! Tycho, most celebrated glory of

the Danish people: it pleased you to behold such obstacles, yielding to no human strength, and to bring to the labor a Herculean aid, which Atlas himself did not well endure. Skilled one, give us the instruments — the greatest and best — which you know how to construct, and which your book here shares with the World: by which, for thrice-seven years [twenty-one years], you have surveyed unceasingly the bright stars, both fixed and wandering, throughout the whole heaven. Each one of them, by an easy revolution, though once trackless, you have brought to a rule, to which the whole aether yields obedience.

O Danes, thrice and four times blessed, to whom the stars granted that this great man should be born! But a greater glory now rises for you (who could have thought it possible?), because you did not begrudge your foster-son, whom Germany [Teutonia] could have kept, to be ours [?]. Perhaps that supreme God of gods willed this, so that the glory of Urania might penetrate into all lands. O Frederick, father of the fatherland, whose memorable name flourishes in the World — yours is no small praise, that, receiving Tycho, you freely fostered the noble labor that touches great souls and noble hearts, and will raise its renowned cultivators to Olympus. But because Tycho, you now leave your native shores, bear it with a lofty spirit, as indeed you do: every land is a homeland to the great-souled. Hail, dweller of the World, son of the North and of Denmark! Go on, illustrious Tycho — go on the more to spread your praises through the World; press on to weave through to the end the eternal work for the eager; press on to bring forth the pledges of your surpassing genius with rich fruit. And thus the coming ages will speak your name ever more abundantly, as long as the golden-haired sun [Cynthius] shall number the years, as long as the wandering Moon shall change her horns through the months, and as long as the stars shall shine throughout the whole heaven.

[Margin / subscription:] To testify to my fidelity and respect. — FRANCISCUS GANSNEB TENGNAGEL [Frans Gansneb Tengnagel], with his own hand [F. / manu propria].

A BRIEF NOTICE CONCERNING CERTAIN OTHER OF OUR INSTRUMENTS NOT YET ENGRAVED

Up to this point I have exhibited and explained our astronomical instruments — as many as had been drawn and engraved — so far as was possible for the present. But I still have ready at hand certain others, which, since they have not yet been depicted and cut, it was necessary to omit here. I shall, however, take pains that, as soon as it can be done, they too may be joined to the earlier ones,

and that this whole treatise on mechanics may be more fully expanded, with the addition of certain aids and tables conducive to it. In the meantime, I shall nevertheless touch briefly here on some of the remaining instruments.

THE BIFURCATED SEXTANT [SEXTANS BIFURCATUS]

We have also constructed a certain sextant — which, because it has rules running out from the center on either side that can be drawn together and spread apart, crossing one another by sliding, is for that reason called "bifurcated" — which has a steel arc comprising a sixth part of a circle. The length of the rules is 4 cubits. It also has brass sights variously arranged off-center near the ends of the rules, on either side. The rules themselves are of Brazil wood, since that is compact and durable. It has its divisions made in the arc in our customary manner. The distances of the stars can be examined quite precisely with this sextant by two observers, each of whom sights through the sights of his own rule — except that, with somewhat greater effort than in the other sextants, it is not accomplished so quickly. It is nevertheless, since it is thereby easily portable, convenient for occasional uses.

A LARGE SEMICIRCLE FOR MARKING OUT GREATER DISTANCES IN THE HEAVENS [SEMICIRCULUS AMPLUS PRO MAJORIBUS DISTANTIIS COELITUS DENOTANDIS]

Since by the sextants devised and prepared by us only those distances of the stars can be observed which are comprised within a sixth part of the heaven, and since it sometimes happens in use that distances greater than these must be searched out in the heavens — so that occasionally distances greater than a quarter of the heaven must be marked out, when the convenience and use of observation requires it (which for the most part has its place in the greater distances of the Sun and Moon, when around either quadrature or beyond, they are sometimes seen together by day; and also on other occasions) — for that reason we have had a certain semicircular instrument made, secured on all sides by transverse framing-timbers, and firmly overlaid with brass plates both on the circumference and on the diametral rule. By its aid the intervals of the stars, however great they may finally be, can be measured exactly up to the completion of a hemisphere. This semicircle has 6 cubits in its diameter; and around the middle of the whole structure, where it is, as it were, in equilibrium with itself on all sides, there is a square hole, in which

a strong support — especially a globular one — is set in place during observation, and it is directed into the plane of the stars by two observers; and its use is set up no otherwise than in the sextants. Therefore there is no need to add more about this; but let the expositions of the sextant for taking distances be consulted, if anyone desires further details.

THE ASTRONOMICAL RADIUS [RADIUS ASTRONOMICUS]

We do not entirely shun the use of the astronomical radius [cross-staff] either — especially when traveling, since it is easily portable and is enclosed in a very small case — provided that it furnishes the most exact and plainly indubitable distances of the stars. Such a one I have at hand: not built by myself, indeed, but fashioned by Gualterus Arsenius [Walter Arsenius], nephew of that most excellent mathematician Gemma Frisius [Gemma Frisius] — who once lived at Louvain in Belgium and who published a little book about it. It is composed entirely of brass plates skillfully fitted together, although it is wooden within; and it has sights and divisions, just as it is described by the same Gemma in the said book. Its longer rule, or the radius itself, is a little more than three cubits; in thickness it is everywhere quadrilateral, of about the width of a large thumb; the transom is about half of the radius itself, both in length and in breadth.

Moreover, I have also taken care, through my craftsmen, to have another radius made — likewise entirely of brass, but hollow within and packed with no wood. For wood has this nature: that unless it is aided in some special way, it forces the brass plates with which it is overlaid to incline in the direction toward which it is drawn by its own instability and by the change of the air. But that radius which we afterward made is not quadrilateral but trilateral, so that it might be lighter, and these three surfaces suffice for marking all the divisions on it. And I made the divisions on it equal, by the transversal points [puncta transversalia] customary with us, so that it might equal a Canon of Sines of five ciphers [figures], and might execute everything more subtly than the aforesaid radius of Gemma — with the unequal division too arranged otherwise, since that one is faulty in his version. Its length and breadth, and the whole proportion, are nearly equal to the earlier one; and it has similar sights.

But, to say what the matter truly is: a radius, however it is prepared, does not supply (as I have noted before too) the exact distances of the stars — not even those narrower ones within 15 degrees, still less the wider ones, in which it errs even more. The reasons for this it would not be difficult to set forth elsewhere; here I aim at brevity. I have nevertheless myself devised a certain means by which the difficulties and hallucinations [errors] of the radius are entirely

remedied — applying to it as well sights having slits, and a cylinder, around which the distances may be examined by two observers, no less than in the sextants. About which I shall say more elsewhere, when it has been prepared (for it is now under construction), God willing.

THE ASTRONOMICAL RING [ANNULLUS ASTRONOMICUS]

We also have ready an astronomical ring [annulus astronomicus] — an instrument adopted because of its handiness by many others, both ancient and recent — made some years ago by the same nephew of Gemma, in imitation of that description which the same Gemma set forth in a concise little book. And this ring is entirely of brass and skillfully composed. It has about one cubit in diameter. To this we have added another contrivance within: namely, oblong and rounded cylinders passing through one another crosswise and at right angles, grazing the inner surface of the armilla and there fitted into place by a square support; and also with sights, and certain other devices, it has been so provided by us that it not only performs, far more conveniently, what Gemma and others have transmitted about the use of this ring, but furnishes besides certain other things. For thus it will be possible not merely to take the Declination of the stars more aptly than before, but also their differences [right ascensions], and so the right ascensions [adscensiones rectae], to be marked out directly from the heavens — to say nothing of the longitudes and latitudes of the stars, which can also be obtained by a certain special procedure applied; and more about these matters, when the Instrument has been formed and cut, we shall treat at greater length, God willing.

But

But whatever one may make of this, instruments so small and trifling cannot be used to investigate the celestial appearances with sufficient precision. The reason is that, because of their small size, they do not allow the degrees to be subdivided into the small parts of minutes; and if they were made of any considerable size — so as to permit this — they become unmanageable by their bulk and weight, and moreover they are themselves further weighted down, so that they are not suited to use without some error.

I also have another, smaller ring of brass [orichalcum], measuring at most the length of a contracted span [spitamen] in diameter. But this one I find even less satisfactory.

The chief use of such rings is to distinguish the hours of night and day by them. Yet they do not perform this with the ease and precision they promise. They are nevertheless in some degree suited to the purpose when other and more reliable means are lacking — especially since, by their portability, they are conveniently carried about. The other uses that Gemma [Gemma Frisius] and others have heaped together are less important, and those who wish to know about them with no great certainty may look for them in their books.

ARMILLA PORTATILIS [The Portable Armilla]

There is also a certain single armilla [ring] that I have made, steadied nonetheless on the inside by suitable supports, which could easily be carried out and set up in the open air upon stone pedestals with screws fitted to them, and so be turned round, conveniently and with the least trouble, toward any part of the sky. By means of these rings, the declinations of the stars are taken — though not so finely as with those larger ones discussed in what precedes. Yet since this armilla is nearly 3 cubits in diameter, and its circumference is everywhere overlaid with brass [orichalcum], so that it expresses the individual minutes of the ordinary degrees by transverse points [puncta transversalia], it serves not uselessly for taking declinations. And I make most use of it when the stars approach the horizon. With those larger ones, on account of their crypts [the buried/enclosed mountings], should any be brought there, this hindrance might perhaps not be carried out so conveniently; and also for other reasons, by which sometimes greater convenience for performing this task at certain particular places is afforded in these instruments than in those larger ones; and also so that, by the variety of instruments, the same result that is obtained may be confirmed.

To this armilla one may also, whenever desired, adapt a semicircle, an equator, and a smooth cylindrical axis; and thus accommodate it to several uses — namely to taking right ascensions and the moments of time by it. This too I have sometimes been accustomed to do.

ASTROLABIUM [The Astrolabe]

The astrolabe is an instrument used by the ancients, and especially very much by astrologers, and (as I believe) first cleverly devised by the Arabs. Compressing the circles of the celestial sphere together with their use into a plane, it sets them in order. I have so far not wished to have any one of full size made, because its use is less suited to observations of the stars, and is not sufficient or reliable for them. I do, however, possess a small one bought with my own money, solidly and skillfully wrought of brass [orichalcum], which equals in diameter only the length

of a larger span [spitamen]. And it is composed, with its plates [matrices], according to that old method which Johannes Stoefflerus [Johannes Stöffler] and others who followed him have set forth clearly. Anyone who wishes may ask them for its construction and use.

But some years ago at Nuremberg [Norimberga] I had round brass [orichalcum] plates carefully made, more than 2 cubits in diameter and of a thickness appropriate to this, on which I resolved to work out subtly a Catholic, or Universal, astrolabe — one which, without [interchangeable] plates [matrices], on just two faces would supply everything that can be taught concerning the whole doctrine of the first mobile [primum mobile], and everything that can otherwise conveniently be shown on a spherical body, which this instrument represents in a plane. And therefore I am also inclined to add to it that peculiar feature, and to mark it with the principal fixed stars — and indeed with many more than were in use among the ancients. This astrolabe would perhaps surpass, by a certain convenience of its own, that invention of de Royas [Juan de Rojas], and another still more agreeable one afterward devised by Gemma Frisius, by its convenience and subtle method, and would be still more universal.

But up to now the opportunity to put together such an astrolabe has not been given me, on account of the making of the other instruments and the manifold pressure of my affairs. This I have left unfinished all the more willingly, since its use does not properly and precisely explore the motions and places of the stars, but presupposes those to be already known from elsewhere; and also because the fixed stars, with which it ought to have been marked, we had not previously fully explored according to their own restitution [restitutio] — stars which, now that they are exactly settled for us by divine favor, it will not be difficult, once some such leisure is obtained, to construct an astrolabe of this kind; especially since the brass [orichalcum] plates prepared long ago for these uses, as I said, are still in part preserved with me.

DE ALIIS QUIBUSDAM INSTRUMENTIS ASTRONOMICIS [On Certain Other Astronomical Instruments]

[Subtitle, as printed:] Astronomical instruments by which, with marvelous economy, many things may be carried out, which I lately devised and resolved to construct in due time, God favoring it.

Now the instruments already recounted above — so variously depicted and explained — together with those afterward briefly indicated, we have all ready and on hand. And although by their variety and abundance they may suffice for every kind of observation of the celestial bodies, nevertheless, since I silently foresaw that the necessity of migrating from Denmark, my sweetest homeland, was pressing upon me — lest I should abandon, in a manner not to be praised, these studies, pursued through so many years, with such great effort and the greatest expense, right up into the third seven-year period, which is usually climacteric and subject to changes — I began to consider with myself whether it might not be possible to devise some other astronomical instruments which, with fewer requisites, would exhibit conveniently and reliably everything that the rest erected there exhibit; instruments which also would not lack the ease of being conveyed to any other places whatever, if perhaps I could not arrange to have those that I possess there transferred to me quickly enough and without inconvenience.

Therefore, by divine favor, I am certain that I have lately devised several of this kind. Among them are certain perpetual rules [regulae aeternae], which will suffice not only for taking the altitudes of the stars, as those Ptolemaic ones do, but also for investigating their distances; and which can be aptly put together and transported into whatever place. Moreover, I have devised an armillary instrument, consisting of only one and a half armillae, which will not only investigate the declinations and right ascensions of the stars, but will also most easily disclose their longitudes and latitudes, and at the same time, if it be rightly disposed for those uses, will suffice for observing the altitudes and azimuths. Indeed, it will not shrink from yielding the distances of the stars, if one chooses to use it so; and thus this single one will be a match for uses of every kind, and can without difficulty be disjoined and put together whenever one pleases, and be transferred into other regions enclosed and protected in its case.

Besides this, another scheme also occurred to me: how the same instrument, most compendious and most useful, might be formed by means of long rules composed and connected in a square and triangular shape with few intermediate parts, so that it would grant equally everything that we said of the former mode, and also certain other things, if it should seem good so.

This will have this advantage over the preceding one: that, disjoined and put together, being enclosed in a narrower space and a straighter [more compact] little chest — namely, in an oblong [case] — it can be transported still more conveniently into one place and another; and also it can be made at less cost than

the preceding. Lastly, I have imagined yet another instrument which, with a single circle (could one think it possible to be made?), is suited to the skillful investigation of the declinations and right ascensions of the stars, as well as of their longitudes and latitudes, and also of their distances, altitudes, and azimuths. This too one may construct in a square form, though not so conveniently. Indeed, these very things can be done, in a manner, on only a half of a circle, or even on its third or fourth part — though not so concisely and universally, but in a certain partial way, and sometimes by combination. These, however, when duly performed, will yield precisely and reliably the very thing that is sought.

But concerning these and similar things which I have so far devised, partly of late under the urging of necessity (which, as the saying goes, teaches the arts), partly such as I shall devise in time to come by the kindness of the same divine power, I shall scarcely publish anything publicly, lest such rare inventions, once laid open to all (as commonly happens), should become cheap. But to illustrious and princely men only, who are deeply devoted to such things — whose part it also is to be more excellently imbued than other men with these sublime studies, and to cultivate them liberally and laudably — when their gracious will toward me has been made plain, I shall not refuse to disclose and explain these matters, provided, however, that they keep them secret.

GLOBVS MAGNVS ORICHALCICVS [The Great Brass Globe]

Diagram. A full-page engraved plate depicting the great brass [orichalcum] globe of Tycho Brahe, mounted within a meridian ring and a horizon circle, set on a stand, with a hemispherical lid or dome raised above it. The plate is headed by a laurel-wreath cartouche (motto/text within illegible [?]) above the title "GLOBVS MAGNVS ORICHALCICVS." The celestial globe is engraved with constellation figures (the zodiacal and other constellation images are visible across its surface) and is crossed by graduated great circles (the ecliptic and equator) bearing degree numerals along their bands. The globe rests in a horizontal horizon ring (a broad flat table-ring) and is held by a graduated meridian/colure ring; the whole is supported on a crossed-leg stand with a small armillary base, resting on a rocky/ground base with feet (spheres) at the corners.

Labeled elements (letters engraved on the plate):

- Y (open field to the left of the dome/cap, mid-height): prominent open-field point-letter, left
- Z (open field to the right, at the meridian-ring outer edge): prominent open-field point-letter, right
- L (horizon-ring rim, left side): point on the horizon circle
- A (horizon-ring rim, immediately right of L): point on the horizon circle
- M (horizon-ring rim, front-center): graduated front of the horizon circle
- K (lower left, on the meridian graduated ring): point on the meridian ring
- C (horizon-ring rim, right side): point on the horizon circle
- G (horizon-ring rim, front-center-right): point on the horizon circle
- P (meridian ring, below the horizon ring): point on the meridian ring
- O (base/leg cluster, upper-left of feet): point at the base
- H (base/leg cluster, center): point at the base
- R (base/leg cluster, right): point at the base
- S (left base block / foot): foot at base
- X (right base block / foot): foot at base
- [?] (right edge, below the dome rim near the horizon ring): uncertain point-letter (reads "II"/"H")

Degree graduations are numbered along the meridian ring (numerals 70, 60, 50, 40, 30, 20, 10 — a 0–90° quadrant graduated every 10°, "70" highest near the dome rim, "10" near the horizon ring). The raised hemispherical dome (a ribbed/segmented cover) hangs above the globe by a ring at its apex.

[Margin note / point-letters and the meridian-ring degree band recovered on the scan at high magnification; one right-edge mark remains uncertain ([?], reads "II"/"H").]

Explanation of the Construction and Use

We took care to have this globe — the largest of all — made with the utmost diligence and at no less expense than all the rest. It does not, however, consist of wooden material throughout: it is assembled from cunningly fitted rings and small interlocking pieces, braced here and there from the center, and then turned into a spherical shape. As for the wooden frame of this work, I arranged to have a suitable craftsman make it at Augsburg [Augustae Vindelicorum] in the year 1570, before I left there to return to my homeland — having long sought such a man elsewhere in vain. Because of its great size, which posed no small difficulty

to the maker, the work dragged on at Augsburg into the fifth year, by which time I had returned there. Indeed, in the year 1575, when I was passing through Augsburg on my way back from Italy at the time of the coronation of His Most August Majesty the Emperor Rudolf II [Rudolphi II] at Regensburg [Ratisbonam], I found that globe — long since finished — but it was by no means perfectly round on every side, and moreover was cracked here and there with various fissures.

Nevertheless, the following year I had it brought to me in Denmark, not without difficulty. There its fissures were repaired, and its sphericity was carefully restored by gluing on several layers of parchment. Then, over a two-year period, I made a test to see whether it would shift in any direction — whether it would not retain its shape through the changes of two summers and as many winters. At last, when I found that it consistently held the most perfectly round form on every side, I had it completely overlaid with plates of brass [orichalcum] of suitable thickness. This was done with such care and refinement that you would say the globe was made of solid brass, the seams of the plates being scarcely visible. I then had it smoothed into an exact spherical form. Finally, having marked it with the zodiac and the equator together with their poles, I subtly divided each of their degrees into individual minutes by means of transverse points [per puncta et transversalia] — as has been our practice. Even so, I still left a year's interval before the division, so that a test could be made of whether, after the application of the brass, it would preserve its roundness equally through winter and summer.

When this had been sufficiently established by experiment, I fitted to it not only the circles I have mentioned, but also — most diligently observed and entered at their proper places — the stars of the eighth sphere [octavae sphaerae sidera], as many of them as it was possible to obtain from the heavens. These, increased more and more in number over successive years, at last reached a thousand, so that I fitted to it all the stars, as many as are at all visible to the eye, with their positions deliberately referred to the year 1600 — then shortly to be completed. And so about [?] years elapsed from the first making of this globe until it was finished with its divisions and its stars. Although this delay may seem tedious, it was nonetheless of no little use, in that everything was rendered more consistently, more fully, and more perfectly. And it is soon enough, if it is done well [Et sat cito, si sat bene].

Meanwhile, its outer fittings are the rings: namely the meridian, which the letters E F G H represent, and next the horizon (of which more later), between which the globe itself is enclosed, and on its own axis it revolves about the poles I K. This

meridian is made of solid steel [chalybe], and has divisions of every single minute of all the degrees. The horizon L M N is a span wide [spitamae latitudine], likewise overlaid with brass, and divided azimuthally into its degrees and minutes. From the zenith down to the horizon descends a quadrant of the vertical circles, made of brass, beginning at B and ending at the horizon, and subdivided into 90 degrees with their individual minutes. This serves both for reckoning altitudes upon itself and azimuths upon the horizon.

The horizon together with its meridian — and so the whole globe enclosed within them — rests upon a firm pedestal, represented by O P Q R S T V X. In this pedestal there are two crossbars Q R passing across each other, which can be seen on one side, and two similar ones on the other, for the sake of support and stability, so that neither the horizon nor the whole machine may waver at all, given its great size and weight. This whole base is about [?] feet high. On its lower part various craftsmen of mathematics [varii artifices Mathematum] are seen handsomely depicted by way of ornament, together with certain other things adding to its beauty. The globe itself is close to 6 feet in its diameter. From this the meridian, the horizon, and the rest can be estimated.

I judge that a globe-machine so solid and so finely wrought, and everywhere so duly and consistently constructed, has been built and completed by no one until now (let it be said without envy) in any part of the world — a great and magnificent work. To see it, along with my other instruments, many people from various regions journeyed to Denmark, while the inhabitants of Uraniborg [Vraniae incolumae] and the renowned castle stood about it. Around the horizon these words are read in golden letters:

> IN THE YEAR 1584 AFTER THE BIRTH OF CHRIST, IN THE REIGN OF FREDERICK THE SECOND IN DENMARK [FRIDERICO SECUNDO], TYCHO BRAHE, SON OF OTTO [O. F. — Ottonis Filius], RESOLVED TO REPRESENT EXACTLY THIS GLOBE, CONFORMABLE TO THE CELESTIAL MACHINE — ON WHICH THE STARS OF THE EIGHTH SPHERE, FIXED IN THEIR PLACES AND DETECTED FROM THE HEAVENS BY INSTRUMENTS, ARE SET EACH IN ITS OWN PLACE TO A NICETY — AND TO INVESTIGATE THE WANDERING STARS THROUGH THEIR TRUE APPEARANCES: THE HEAVEN HAVING BEEN LAID OPEN BY MECHANICAL WORK TO THOSE EARTH-BORN WHO GRASP ITS PRINCIPLE. HE MADE IT FOR HIMSELF AND HIS POSTERITY. [ANNO A CHRISTO NATO ↃIↃ IↃ XXCIV, REGNANTE IN DANIA FRIDERICO SECUNDO, HUNC COELESTI MACHINAE CONFORMEM GLOBUM, IN QUO AFFIXA OCTAVAE SPHERAE SIDERA

COELITUS ORGANIS DEPREHENSA SUIS QUAEQUE LOCIS AD AMUSSIM REPRAESENTARE: ERRANTIUMQUE STELLARUM PER HAEC APPARENTIAS PERVESTIGARE DECREVIT: COELO TERRIGINIS, QUI RATIONEM EAM CAPIUNT, MECHANICO OPERE PATEFACTO, TYCHO BRAHE O. F. SIBI ET POSTERIS F. F.]

As for why the year here inscribed is 1584: this is because it fell about the middle of the time during which this structure was being made — four years, that is, before the death of King Frederick of most praiseworthy memory, who fostered me and my studies generously and graciously, and pursued me with royal affection as long as he lived. I will add this too: that this magnificent machine has a covering above, indicated by Y Z, hollow within and round, which encloses the upper hemisphere of the globe; and by means of a cord fastened to a beam on a screw, it can be lowered whenever one wishes, to protect the globe itself from dust and other impurities.

The use of this globe is like that of the other celestial instruments — which I intend to describe in a separate book when I have leisure, for it cannot be dealt with in few words. Beyond the others, however, it has this prerogative on account of its size: that everything may be carried out on it most exactly, indeed down to the very minute. And so all matters that concern the doctrine of the *primum mobile*, and the observations of the celestial bodies with respect to the ecliptic and the equator and any others you please, are accomplished here mechanically among the smallest of the circles, with the least trouble and without laborious computation.

On Those Things Which We Have So Far Drawn Forth in the Field of Astronomy by God's Gift, and Which Things Remain Hereafter, by His Same Favor, to Be Carried Out

[DE IIS QUAE HACTENUS IN ASTRONOMICIS DEI DONO EXANTLAVIMUS, QUAEQUE POSTHAC EODEM FAVENTE, EXEQUENDA RESTANT]

In the year of our Lord 1563 — that is, [?] years ago, when the great conjunction of the superior planets occurred around the end of Cancer and the beginning of Leo — in the sixteenth completed year of my age, I was applying myself to the humane letters at Leipzig [Lipsiae], supported there together with my tutor, my

dearest kinsman GEORGE BRAHE [GEORGIO BRAHE], who departed this life about thirty years ago. For my own father, OTTO BRAHE [OTTO BRAHE] of honorable memory, did not much desire that his sons — of whom he had five, and of whom I am the firstborn — be imbued with Latin letters; though he himself afterward regretted this. But the said uncle reared me from my very infancy, and thereafter generously supported me as long as he lived, up to the eighteenth year of my age. He always treated me in the place of a son, and had resolved to adopt me as his heir. For his own marriage was childless: he had taken to wife the most noble and most prudent lady INGER OXE [INGERA OXONIA], sister of that great PETER OXE [PETRI OXONII], later Steward of the Court of the Kingdom of Denmark — a lady who died five years ago, and who, while she lived, embraced me with singular affection as though I were her son. She was afterward for twelve years mistress of the household [Aulae magistra] in the Queen's chambers, in the time of King Frederick the Second of most praiseworthy memory, being succeeded in that same office by my dearest and most honorable mother BEATE BILLE [BEATA BILLEA] for eight years — who even now, by God's grace, is still living, in her 71st year of age.

So it came about, by a certain peculiar chance, that, snatched away in infancy by the aforementioned uncle without my parents' knowledge, I was put by him to the Latin school around the seventh year of my age, and afterward, about my fourteenth year, was sent to Leipzig to continue my studies, where I stayed for three years. I trace this back a little further so that it may be clear by what occasion I was first set to the liberal studies and afterward turned my mind to astronomy, and that I may gratefully recall the memory of my parents and of those who deserved well of me.

Now since I had already, before that, from books in my homeland of Denmark — especially the ephemerides (to grant a pardon to the matter I have settled on) — laid some beginnings of the rudiments of astronomy, to which by a certain natural inclination I was drawn, I then began at Leipzig — though against the will and over the resistance of my tutor, who preferred that I devote my effort to jurisprudence, putting forward my parents' wish (which I nonetheless complied with as far as my age allowed) — to cultivate astronomy more and more, secretly, however, so that my tutor would not get wind of it. Soon I grew accustomed to recognizing the constellations [Asterismis Coeli], all of which, as many as were conveniently visible in that horizon, I learned within the space of a month from a certain small globe — only about the size of a fist — which I used quietly to carry about with me in the evening hours, of my own accord and with no one to demonstrate, just as I never otherwise had the chance to have a teacher in

mathematics. Otherwise I would perhaps have advanced more quickly and further in it.

I soon began to attend to the motions of the planets as well. And since, from their conjunctions [commixtionibus] with the fixed stars — which I observed by means of lines drawn here and there — I noticed, even from that little globe, that their celestial positions did not agree with the calculation, whether Alphonsine [Alphonsino] or Copernican [Copernicео] (although they came nearer to the latter than the former): thereafter I kept watch daily, more diligently, to note their appearances. And from time to time I compared them with the calculation of the Prutenic Tables [Tabularum Prutenicarum] (for I had by my own effort made even this one familiar to me), not trusting the ephemerides — since I had found the Stadian ones [Stadianas], which were then the only ones derived from those numbers, careless and faulty in very many places. But since I had no instruments at hand, my tutor begrudging me them, I worked at the matter from the start as best I could with a certain rather large pair of compasses [circino majusculo], applying its joint to my eye and each of its legs directed, one to the planet to be observed and the other to some neighboring fixed star — or even taking in this way the distances of two planets from each other, mechanically gauging the degrees intercepted according to the size of a circle. Although this method of observing was not exact enough, I was nonetheless led by it to the point of most plainly detecting the intolerable errors of either calculation.

This too was abundantly revealed by that great conjunction of the year 1563 — of which I spoke at the outset, and on account of which I particularly took my beginning from it — in the motion of Saturn and Jupiter. For it deceived the Alphonsine numbers by a whole month, and the Copernican by several days too, though only a few. For its [Copernicus's] restitution in these two planets does not depart so far from the celestial standard, especially as regards Saturn, whom I have observed Copernicus's calculation never to miss in the heaven by more than half a degree, or at most two-thirds of one; Jupiter sometimes yields a somewhat greater discrepancy. Afterward, in the year 1564, I had a certain astronomical radius [Radium Astronomicum] made for me secretly out of wood, according to the prescription of Gemma Frisius [Gemmae Frisii], which Bartholomew Scultetus [Bartholomaeus Scultetus] — who was then also living at Leipzig and, because of our common studies, was a friend of mine — diligently divided by transverse points [per puncta transversalia] derived from his teacher Homelius [Homelio].

Having obtained this radius, I afterward applied myself vigorously to the observations of the stars whenever a welcome clear sky was granted, and often through whole nights, while the tutor slept and was unaware, from the window of a certain

window of a certain [room], I kept watch over taking them, and inscribed them separately in a certain little book, which I still keep among my belongings. A little later I noticed, however, that the angles of the distances — taken in various ways according to the divisions of the radius as equal, and geometrically converted into numbers by the intervening rule of proportions — did not agree with one another in all respects. Therefore, having tracked down the occasion of the error, I devised a little table [Tabellam] by which it was possible to correct the faults of that radius. For I had then no convenient means to have a new one made: my tutor, who controlled the money, did not allow such things to be built for me. And so I carried out many observations with that radius, as long as I stayed at Leipzig, and afterward too, once I had been recalled to my homeland.

Then, setting out again for Germany, I attended to the stars as far as I could, first at Wittenberg [Vitebergae] and soon at Rostock [Rostochii]. About the year 1569 and the following one, while staying at Augsburg, besides that great quadrant which we made in the garden of a consul outside the city (of which more above, in its proper place), I observed the stars very frequently with another instrument — namely a wooden sextant [Sextante ligneo], devised by us there — and recorded the results in a separate book. This I afterward, having returned once more to my homeland, made anew in another similar but somewhat larger one, especially since that admirable new star which blazed forth in the year 1572 had — amid my pyronomic [chemical] labors [Pyronomicis laboribus], begun at Augsburg and then continued, on which I sweated greatly — called me back to the contemplation of the heavens. This star too I observed diligently and described faithfully and accurately, first at that time in a certain small booklet, and at last in a whole volume.

Afterward I had made, one after another, various other astronomical instruments, some of which I carried with me as I traveled again through all of Germany and passing through a part of Italy, where, in the very midst of my journeys, I did not desist from observing the stars whenever opportunity offered. At last, having returned to my homeland around the 26th year of my age, I shortly began to prepare, quietly, for another and more lasting departure. For I had resolved to choose my place of residence at Basel of the Rauraci [Basileae Rauracorum], or in its vicinity, which I had previously surveyed for that purpose,

so that I might there lay the foundations for the restoration of astronomy. For that place pleased me beyond the rest of Germany, both on account of its most renowned university and the men eminently learned there, and for the healthfulness of its air and the convenience of its provisions; and because Basel lay, as it were, at the meeting point of the three most ample regions of Europe — Italy, France, and Germany — so that I might form acquaintance by letters with many distinguished and learned men on every side, and might spread my discoveries more widely abroad for public use. For I had a presentiment that I could not cultivate these studies conveniently and securely enough in my homeland, especially if I were to remain in Scania, at my seat of Knudstrup [Knudtstorpiana], or anywhere in some broad part of Denmark, where there would be a frequent concourse of nobles and friends who, by interrupting my philosophical leisure, would be a hindrance to me in such pursuits.

But it truly happened that, while I was turning these things over in my secret mind, and was already girding myself for the journey as though intending nothing of the sort, the most serene and most powerful King of Denmark and Norway, Frederick the Second [Fridericus Secundus] of most praiseworthy memory, sent to me at Knudstrup one of his noble pages with a royal letter, commanding that I come to him at once, wherever in Zealand he might be found. After I had therefore appeared before him, that best of kings — never sufficiently praised — of his own accord and by his gracious will offered me that island of the most renowned Danish Sound [Porthmi Danici], called Hven [Huennam] by our countrymen (which one may in Latin call Venusia, while foreigners call it Scarlatina), so that I might erect on it buildings and instruments for astronomical exercises, and also for pyronomic labors. He asked me to undertake this, and graciously promised that he would generously provide for the expenses of these things.

The matter having therefore been deliberated for a while, and counsel taken with prudent men, I changed my former intention and acquiesced — not unwillingly — in the royal wish, especially since I saw that on that island, which lies apart between Scania and Zealand, I would be freed from the interruption of those who break in, and that the leisure and opportunity which I had sought elsewhere could thus be granted me in my homeland, to which above all other regions we owe the most. So I soon began to build the castle of Uraniborg [Vraniburgum], suited to astronomical matters, in the year 1576; and successively I completed both the buildings and the various astronomical instruments suited to the accurate carrying out of observations, of which the chief part is set forth and explained in this book.

Meanwhile I also kept vigorously at the observations, having summoned for this service several students of great keenness of mind and strong of sight, whom I continually maintained there and instructed in these disciplines and in several other philosophical ones. And so, by God's kindness, it came about that, with scarcely any clear sky passed over, we obtained very many — and those most exact — celestial astronomical observations, both in the fixed stars and in all the wandering ones, as well as in the comets that shone forth in the meantime, of which we accurately recorded seven there from the heavens. These industrious observations of twenty-one years were carried out in this way, which, first written up in great volumes, I afterward had separately distributed into individual books — one for each year, that is — and fair-copied. And I carried this out with such an arrangement that the fixed stars, those that were noted in any given year, should have their own place; while all the planets had their own place, peculiarly and distinctly, beginning from the Sun and Moon and passing through the remaining five planets all the way to Mercury. For we did not leave even this one unobserved, however rarely it appears. On the contrary, in almost every single year it was diligently noted by us, both at the morning hour and at the evening; although that great Copernicus [Copernicus] excuses himself for not having observed it, on account of the excessive inclination of the sphere and the vapors of the river Vistula. Whereas we

We have very often seen it (as I said) and measured it, even with the sphere still rather more inclined, and on an island everywhere girt by a sea more laden with vapors. But perhaps the dwelling-house of Copernicus was so arranged that it afforded a free horizon on every side, and was therefore less suited to observations — especially of this more sloping kind. This is what that student of mine also reported to me, whom some [?] years ago I had sent there to examine the elevation of the pole. For this reason Copernicus, lacking observations of his own for Mercury, was compelled to borrow some from the book of Observations of Walther [Gualteri], the disciple of Regiomontanus [Regiomontani], a citizen of Nuremberg [Norimbergensis] — which, although he did not apply them to his own tenets and demonstrations faithfully and precisely enough, yet it were to be wished that in the remaining planets, which by a vast effort he labored to restore from his own observations, he had obtained results not much more uncertain. Then surely we would now have far more correct apogees and eccentricities of those planets, and the other things conducing to this end; and I would have been able to spare myself the very great and untiring labors of many years, and immense expense.

Since, then, I have at hand most select and most accurate observations of twenty-one years, gathered from the heavens with various instruments skillfully wrought (which we have displayed in the preceding pages) — to say nothing now of the observations [animadversionibus] of the [?] preceding years — I guard them in place of a most rare and precious treasure. Yet all of these I shall someday perhaps make public, when divine mercy shall have granted me to add still more to them.

From all of which it is clear that I have been accustomed to observing the stars from the sixteenth year of my age onward, and have continued them through almost continuous years, [?], up to the present; among which, however, some are more certain and more excellent than others. For those that I carried out at Leipzig in my boyhood, and up to the twenty-first year of my age, I am accustomed to call childish and doubtful. Those that I afterward obtained, up to the twenty-eighth year, I call youthful and middling. But the third sort, which I afterward made at Uraniborg in a riper age with those most exact instruments — for about [?] years, up to the completed fiftieth year of my age — I call and reckon manly, settled, and most certain. On these especially I strive, by arduous endeavors, to found and build the restoration of astronomy; although several of the observations from the preceding years also contribute not a little to this end.

Now the things which in these matters, by God's help, we have so far accomplished and have worked out, and which remain hereafter, by the favor of the same Divine power, to be carried out and completed, stand thus:

Of the SUN, before all else, we have restored the motion from the most accurate observations of very many years — not only by most accurately investigating the equinoctial ingresses, but also by bringing in along with them the locations of the solstices and the intermediate points, especially in the northern semicircle of the ecliptic; since there the noonday Sun is not subject to refractions. This I have confirmed many times over on both sides, and have thence geometrically deduced both the apogee and the eccentricity of the Sun corresponding to the present times. In each of these an evident error crept in, with the Alphonsines as well as with Copernicus, so much so that the Sun's apogee anticipates the Copernican numbers by nearly three degrees, and the eccentricity is about [?] parts, of the kind in which the semidiameter of the eccentric is 60 — where in Copernicus nearly a quarter part of one is wanting. In establishing even the simple motion of the Sun in these years, he commits an error of about a quarter of one degree. Hence the Alphonsine figures, compared with the Copernican, may be estimated. From this I have deduced canons both of the mean motions and of

the prosthaphaeresis [Prosthaphaereseon], in exact numbers; so that, the Sun's course being verified to a nicety and made evident in suitable numbers, there is no longer room for doubt. And it was altogether necessary that this be done in the Sun before all else, since it is the standard of the celestial motions, and describes the ecliptic, to which the remaining motions are referred. I have also detected its greatest obliquity from the equator to be different from what Copernicus and his contemporaries supposed — namely, 23 degrees 31½ minutes [part: 23. Min: 31½] — and thus greater than their finding by 3½ minutes, by guarding, that is, against the refraction of the Sun in its winter position, which they inconsiderately neglected. We have also provided for the Sun with particular canons of revolutions; and likewise we have added new canons of declinations and right ascensions, founded on our own findings. Moreover, we have made special provision in particular tables for its parallaxes and refractions.

In the MOON too we have employed no less diligence, so that its errors might be resolved — errors that are involved in a manifold complexity, and are not so simple, nor so easily evident, as the ancients and Copernicus supposed. For it has a certain other intimation of inequality according to longitude, which was not noticed by them. Nor did they note the proportions of its circuits precisely enough in it. Moreover, it exhibits other limits of greatest latitude than were prescribed by Ptolemy [Ptolemaeo] — a limit which in this matter all the other astronomers afterward followed too carelessly; indeed, the Moon even varies this very limit unequally, to the difference of a third part of one degree. Nor does it subject those nodes, where its path crosses the ecliptic, to a uniform motion, as has hitherto been supposed, but it makes them nod [nutare] back and forth at each revolution, and that by a perceptible difference, which on either side somewhat exceeds one and a half degrees. Just as we have both observed and restored all these things from the most diligent observations of [?] years — among which are 18 lunar eclipses, accurately noted from the heavens. For [?] observations are not sufficient for investigating its first inequality, as Ptolemy

than [Pto]lemy [Ptolemy], al-Battānī [Albategnius, al-Battānī], and Copernicus [Copernicus] supposed. For this purpose we also called in six solar eclipses, insofar as they could contribute anything to the matter. Besides these, the Moon was investigated in many ways and very often at the quadratures and at its greatest elongations from the mean motion — both around apogee and around perigee — as well as at the intermediate positions, so that its intricate motion could be properly established. This cost us the incredible labor of many years. In the end, however, we discovered the principles by which its unstable and manifold wanderings might obey circles and numbers. And so, once the rest of

the apparatus had been arranged in agreement with the established hypothesis, we fitted the numbers both of the equal and of the unequal motion, not only in longitude but also in latitude. We also worked out its parallaxes differently from how Ptolemy and Copernicus had done, just as experience — in agreement with the one hypothesis — required. Nor did we neglect the care of the lunar refractions, since without these the rest cannot be exactly determined.

All of this, together with some further matters concerning the lunar appearances, we have reduced to concise canons and set aside for the calculation of its motions to be drawn from them. Thus, with the course of each luminary so restored that it corresponds to the celestial appearances themselves, both eclipses and the other configurations, conjunctions, and ingresses will hereafter be able to be established with the utmost accuracy — something long desired up to now. But what has been said thus far about the restoration of the Sun and the Moon, with respect to their motions answering to the heavens, this and much more besides the First Chapter of our *Progymnasmata* of the restoration of astronomy will set forth fully. There the reader eager for these matters will have his wish granted.

It remains only, in the further consideration of these two luminaries, to adapt everything to a span of several centuries and to render it more universal — which can be done without too much trouble, provided that the observations of the ancients and of our predecessors, on which one must rely, are sound. But this fuller and more comprehensive exposition we reserve for the work of the *Theatrum Astronomicum* [Theater of Astronomy]. In the meantime, the student devoted to astronomy will be able to make highly useful use of what we have handed down in the *Progymnasmata* at the place cited, and to satisfy his desire well enough.

Furthermore, we have in the meantime most accurately verified all the FIXED STARS [Stellas inerrantes sive fixas] — every one that is in any way visible to the eye, including even those that are called of the sixth magnitude — both according to longitude and according to latitude, down to the single minute, and indeed sometimes to half a minute of it. In this way a full thousand stars have been corrected by us, whereas the ancients counted no more than 2 2 [recte: 1022?]; for one dwelling in a clearer sky could discern over 200 [?] that are always hidden from us here. In their place, however, we have substituted others, small ones, which they passed over on account of their smallness. We labored at this arduous work for nearly 20 years, since we wished to test the whole matter accurately with various instruments. But since the tiny stars are seen only in winter, when the nights are dark and the Moon is also below the horizon, the expectation of

many years was required before these could be properly and sufficiently completed — especially since one must take them in hand chiefly around the new moons, when it was rarely clear.

By what method we arrived at an exact knowledge of the fixed stars in respect of their longitudes from the equinox — by means of Venus, both as morning and as evening star, with the Sun as intermediary — and confirmed this very thing in many ways, referring everything to the one that is brighter, above the head [i.e. of Aries], the third in number (which we deliberately set up as the foundation of the rest, since the two earlier ones are less conspicuous): all this the Second Chapter of the said *Progymnasmata* will fully explain. By the same reasoning we have derived the others from this. And first, how by a threefold method we have carried out the [?] of the brighter ones throughout the whole circuit of the heavens along the Zodiac and the equator [?] [the line here is heavily abraded — region uncertain].

I have also observed that there is not so great a complication of inequality in their longitudes as Copernicus supposed. For the things he imagined about these crept in through the fault of observations, both ancient and recent. And so the precession of the equinoxes is not as slow in these years as he held. For the fixed stars do not now complete one degree in a hundred years, as his calculation has it, but only in 71½; which, both before and almost always — if the observations of our predecessors are rightly fixed — they were accustomed to do, with only a slight irregularity besides, occurring accidentally from another source. This we shall, in its own time and God willing, open up more fully.

Indeed I was the first to discover that the latitudes of the fixed stars are altered somewhat by the variation of the obliquity of the ecliptic, and I demonstrated this in the said Chapter by various examples. And thus we can testify abundantly — and experience itself will support us — that the places of the fixed stars have been verified by us with the utmost and infallible accuracy, so much so that we have many times confirmed very many of them with various instruments as well, each one coinciding into a single result. Nor have we carried out this business mechanically, however ready to hand the great brass globe [Globus maximus Orichalcicus] was. Rather, we have laboriously reduced all the stars to their proper places by triangulation [per Triangulorum rationes]: as is evident even from what we set forth concerning the asterism of Cassiopeia [Cassiopea] (in which we count twice as many stars as the ancients) toward the end of that same Chapter — although we also used several applications of triangles and other

reasonings, now with these stars and now with those, as seemed more convenient.

If the ancients and our predecessors had applied such diligence in noting the places of the fixed stars, their reckoning, handed down to us from Hipparchus [Hipparcho, Hipparchus] onward, would by no means have been so faulty. As it is, it is not even reliable in that sixth part of a degree which alone it gives, but often suggests a far greater and intolerable deviation. This even the intervals between the stars alone — which always

remain unvaried — clearly show. For in very many stars these intervals are far otherwise than the numbers of the ancients require. That the fixed stars all stand perpetually in the same intervals with respect to one another, those stars sufficiently prove which Hipparchus and Ptolemy reported to be in one straight line together — since this same alignment still remains unchanged. Of those fixed stars whose longitude and latitude we have restored to the single minute, and sometimes (as was said) to half of it, we shall give a canonical exposition in its own time and place.

Nor were we occupied only with establishing accurately the longitudes and latitudes of the fixed stars; but in certain principal ones, 100 in number, we also derived their right ascensions and declinations by triangulation, and adapted them to two centuries in such a way that for each intermediate year one could be supplied proportionally well enough. We have moreover provided for the refractions of the stars by a special table, constructed from long and manifold experience. For unless these are guarded against, the very places of the fixed stars — especially where they approach the twentieth degree of altitude above the horizon — cannot be obtained. Therefore in the places of the stars corrected by us we have always made allowance for the suggestion of the refractions [?] wherever there was need. These refractions, moreover (to note this too in passing here), behave somewhat differently in the stars than in the Sun. And in this they also differ somewhat from those which the Moon introduces — as we have long since both disentangled and made plain.

Thus nothing else is now lacking in the fixed stars except that their universal motion should be supplied and adapted to all the ages of the world. To accomplish this accurately would not be difficult, if only the ancients' observations on these matters had not been taken in too loose a manner. Yet with a suitable limitation applied, in this part too, so far as it can be done, I am confident I shall satisfy the more cultivated students of astronomy.

It would be desirable, however, that the remaining stars noted in antiquity, which do not appear in our climate, should be added to the first thousand verified by me; and likewise others which not even the ancients dwelling within Egypt could discern, which lie toward the antarctic pole. For we have learned, by the report of those who have sailed beyond the equator, that the most beautiful stars shine there as well. As for the first point, one would have to journey into Egypt or a similar location in Africa, and there carefully note however many stars rise. For the second, to obtain it, one would have to sail to the more southern America or to some other region beyond the equator, where all the stars around the antarctic pole are seen, and there their observations would have to be undertaken. Therefore, if any illustrious and powerful lords were not unwilling to assist our desire and that of others in one or the other — or both — of these matters, they would truly accomplish something outstanding, and worthy of being celebrated in everlasting memory to the renown of posterity — since, so far as is known, this has up to now been duly attempted by no one, let alone fully achieved. And I, for my part, shall not refuse to furnish the instruments and means conducive to this, provided there be those who wish to procure this and to provide suitable men for so praiseworthy a task.

Finally, we have not left untouched the task of scrutinizing the errors of the remaining five PLANETS [Planetarum] and of helping to correct them. Rather, in all these matters we have set in order, as the chief requirement demanded, both their apogees and their eccentricities, and also their simple motion and the proportions of their orbits and circuits, so that they do not swarm with errors as hitherto. And in the apogees themselves we have detected a certain further inequality not previously perceived. Likewise we have found that the annual circuit — which Copernicus accounts for by the motion of the Earth in the great orb, and the ancients by epicycles — is subject to a certain variation. For all these matters, and the others pertaining here, we took counsel from a special hypothesis discovered and established by us, from the appearances themselves, more than 14 years ago — which certain others, among whom I know some notable men, afterward were not too brazen-faced to claim for their own invention and to peddle to others. In its own time and place, God willing, I shall point out the occasions of these things, and shall check and refute their excessive license, and shall prove so evidently that the matter stands thus, that there will be no room for hesitation or contradiction for anyone endowed with sincere judgment. But I shall spare them if they frankly confess the wrong admitted and restore to me what is mine. And so I willingly refrain from naming them for now.

We have likewise not allowed the latitudes of the planets to remain uncorrected, as our predecessors did from Ptolemy onward; but, attending diligently to these in all five planets throughout the whole circuit, we have defined their high points [?] and their other passages through the ecliptic, so that everything may be congruent with the heaven itself. In these matters we have clearly observed that the nodes — that is, the limits of the greatest latitudes — of the three superior planets are not, conformably, subject to the motion of the apogees, but possess another, proper to themselves; provided that what Ptolemy handed down about these is sound — from whom both the Alphonsines [Alphonsini] and Copernicus borrowed theirs, applying no correction of their own from observations. From this it comes about that the planets are sometimes southern in the sky when their numbers exhibit them as northern, and vice versa.

There remains, therefore, nothing else to be worked through in the five wandering stars except this: that these matters concerning the longitudes and latitudes, and everything pertaining here, which stand otherwise than the customary tables report — now derived from the heavens, for more than 25 years (to say nothing of the prior thousands), from accurate observations

explored and established — should be reduced into new and competent canons, set forth in numbers, of which indeed certain beginnings and foundations have already been laid by us. The rest can be completed without difficulty by several calculators, and afterward ephemerides for as many of the following years as one pleases can be unfolded from this. The same can be accomplished for the Sun and the Moon, whose tables we already have ready to hand, so that for future times it may be possible to establish with the least trouble that the motions of the celestial bodies restored by us agree with the appearances themselves and stand correct on every side.

It would contribute very greatly to the complete embrace of all astronomy to have rightly known not merely the latitudes, but much more the longitudes, of terrestrial places. In this part we have hitherto labored diligently, so far as was permitted, and we are persuaded that we have rightly placed and ordered some of them. But since this business is not sufficiently met unless, in diverse and far-distant places, several lunar eclipses are recorded with equal diligence — as to the moments of time — by diverse observers as well: if in this part too kings and princes and other illustrious and powerful men, existing in the scattered regions of the terrestrial globe, would apply a generous and suitable provision, they would indeed accomplish a great service. And thus astronomy, insofar as it has need of the differences of terrestrial horizons, would become more complete.

Further, with unwearied zeal over very many years we have attentively studied the heavenly bodies coeval with the world and those perennial ones; and we have scrutinized with no less diligence the adventitious bodies of that same aetherial world, however many shone forth in the meantime. And first, that New and exceedingly marvelous Star [Nova illa Stella] which began to appear around the end of the year 1572 and lasted for 16 months before it plainly ceased to be visible. Concerning that Star (I say), while it still endured, we composed a certain little book (as we also briefly intimated above), and we displayed its appearances. But after some years, taking up this concern again, on account of the greatness of the marvel we put together a whole volume about it, which for certain reasons made plain in that place we chose to insert into the First Tome of the *Progymnasmata*. There I not only set forth fully my own observations on this stupendous star and demonstrate them geometrically, but I also examine with philosophical freedom the views of others, however many I was able to learn and obtain about it, and inquire whether or not they accord with the very truth, and bring this out into the open.

Concerning the Comet of great appearance, too, which followed five years later [i.e. 1577], we prepared a special book, in which we likewise treat sufficiently of it, both from our own observations and decisions and from the opinions of others, to which we add certain apologias bearing on this and more fully elucidating this cometary business; and we wished to fill out with all this the first part of the Second Tome of the *Progymnasmata*. In the other part we shall in future, God willing, be occupied with the remaining six lesser comets, which we noted with equal diligence over several successive years. Although these are not yet quite finished, nevertheless the chief and great part of them, which serves for the demonstrations, has been prepared. For those perpetual stars [siderea] did not leave us leisure to linger too long over these fleeting and quickly passing things. Yet I hope shortly, by the divine goodness, to complete this other part of that second volume too. In it I shall clearly demonstrate, concerning all the comets I have designated — in some more openly, in others, where the convenience [?] of the observations was not sufficient, [?] — that they were all situated in the aetherial region of the world, and by no means in the sublunary air, as up to now Aristotle [Aristoteles, Aristotle] and his followers have vainly persuaded us for so many ages.

But as to why I treat of comets in the Second Tome of the *Progymnasmata*, before I betake myself to the remaining five planets, of which I intend to treat in the third: I give the reasons in the Preface there. Of these the chief is this, that from the comets — which I prove to be truly aetherial — it can be sufficiently

established that the whole heaven is most clear and most fluid, and not stuffed with hard and real orbs; since these comets for the most part observe other paths than any celestial orbs could afford, and consequently the hypothesis discovered by us admits no absurdity, since there occurs no penetration of orbs and dimensions, where none are really granted.

And let it suffice to have thus indicated in brief these matters in ASTRONOMY [in Astronomicis] — partly already carried through, partly still remaining to be done.

In ASTROLOGY [in Astrologicis] too we have devoted no contemptible effort to scrutinizing the effects of the stars, so that this also, vindicated from errors and superstitions, might for the most part be consonant with the experience on which it rests. For to find in these matters the most exact reasoning, equal to geometrical and astronomical truth, I judge less than possible. But since I had in my youth been rather intensely devoted to this prognosticating part of astronomy — which is divinatory [mantica] and conjectural [Stochastica] — and afterward, on account of the motions of the stars on which it is founded not being sufficiently understood, had set it aside until this inconvenience should be remedied: once the paths of the stars had at last been more exactly ascertained, and taking it up thereafter into my hands, I discovered that there underlies this knowledge a greater certainty than one might easily suppose — empty and vain though it be held to be not only by the common crowd but also by most of the learned, and indeed by some mathematicians among them. And this both in meteorological influences and predictions and in genethliacal [Genethliacis, natal] ones, provided the times

are rightly determined, and the motions and ingresses of the stars are applied in harmony with the heavens, and the directions and revolutions are rightly administered. In these two matters we have also constructed for ourselves another method, drawn from experience itself, than has hitherto been customary. But we do not gladly impart astrological matters of this kind to others, insofar as we hold not a few things explored in these — since not all know how to use discreetly that which is to be used with the circumspection it deserves, free from superstition and from excessive confidence, which is to be attributed to no creatures. And so we shall publish either none or very few of our findings on these matters. Therefore let it suffice to have now said this about them briefly and in general terms.

Moreover, in spagyric preparations, or pyronomic exercises [Pyronomicis exercitiis], I have expended no slight care — to indicate this too in passing here — since the materials which it treats are analogous to the celestial bodies and their

influences. And so I am accustomed to call it terrestrial astronomy [terrestrem Astronomiam]. In knowing and handling this, occupied with it no less than with the celestial since my twenty-third year of age, I have up to now tested many things, with much labor and no mean expense — in metals as well as in minerals, and also in gems and in vegetables and growing things, and in other materials pertaining here. About these I shall not be reluctant, as occasion offers, to confer frankly with illustrious and princely men, and with others distinguished and learned who are attracted by such things and have some knowledge of them, and to communicate some of these matters to them — provided I am assured of their good will, and that they will keep these secrets. For it is neither expedient nor right that such things be made common. Nor is it granted to just anyone — though many profess such things — to carry out these mysteries duly, according to the requirement of Nature, harmlessly and usefully.

Lest the following pages stand empty, it seemed good to add three letters, which two most distinguished men wrote to me concerning the astronomical undertaking: of which one is from the most noble and eminent Jacob Curtius [Iacobus Curtius, Jakob Kurz von Senftenau], of excellent memory, formerly Vice-Chancellor of the Empire. The remaining two are from Giovanni Antonio Magini of Padua [Iohannes Maginus Patavinus, Giovanni Antonio Magini], a most excellent mathematician and astronomer among the Italians — so that even from these it may in some degree appear what hope these men, prevailing by their distinguished judgment, conceived of me in this Art; many similar letters from whom are kept by me. These alone I thought should be added, lest I should seem excessive in such matters. But that I may someday satisfy the splendid expectation of these and of others concerning me, I strive with all my might: and may GOD bring it to pass.

THERE FOLLOWS THE TEXT OF A LETTER

of the most eminent and noble gentleman, Lord

JACOBUS CURTIUS [Jacobus Curtius a Senftenau], FORMERLY VICE-CHANCELLOR OF THE EMPIRE,

WRITTEN TO TYCHO BRAHE IN DENMARK

IN THE YEAR 1590.

S. P. [a salutation: "greetings"]

I give you great thanks, noble and most learned sir, for being willing not only to address me with your letter, but also to show me your goodwill so warmly. To be

sure, although I have not seen your face, I have nonetheless long since both loved and admired the better part of you — your mind, that is, as expressed in your writings, by which you have already consecrated yourself to eternity. For that reason I have keenly longed to see, to revere, and to embrace you in your entirety — no less keenly than those of old who set out from the farthest borders of Spain to come to the city to see Livy. This most gracious greeting of yours has increased that desire of mine, and increased it so far that, were the Emperor's wishes and the duties of the public office I hold not to forbid it — then, so help me God, neither the hardship of breaking off the journey, nor the love and allurements of my most charming wife and my dearest children, would hold me back from setting out for you in Denmark, taking as my traveling companion our mutual friend Thaddaeus Hageccius [Thaddaeus Hagecius / Tadeáš Hájek]. I cannot say how greatly it delights me to range over all of Hven [Hven] with Hagecius — in mind, since we cannot do so in body — and above all to take in, even if only by imagination, your most exact observatory Instruments, the whole of that mathematical apparatus. And what if I were present as a spectator myself, and could see you not merely explaining everything but actually performing it? But since that is something one may wish for, yet scarcely hope for at this time — for I have not utterly cast away all hope — I now set the wish aside, and turning to your letter, I will reply in a few words to its main points. And this first of all.

As to your kindly asking my judgment of your writings, and submitting them to my censure — a censure which, between you and certain most learned men, is not so much a dispute as a friendly contest — in this I take it that you grant me more honor than I would receive even if kings and princes, contending over whole kingdoms and provinces, were to appoint me their judge. But that I should actually take upon myself what you ask and offer — neither my learning, which in me is either none at all or truly slight, nor my modesty permits it. Yet, so as not to be wholly deaf to so friendly a request, take this. As for what I think in general about your writings, the privilege of His Imperial Majesty will bear witness — which I send to you enclosed with this letter, and of whose composition in such terms I was the author with the Emperor, and further its guarantor, vouching that the Emperor was testifying the truth in it. In particular, as to those things you have written about the more recent comets — as many as you yourself observed, and which you have set forth confirmed by the most solid reasonings — I judge these to be such that they can no longer even be called into doubt by learned men. And so I am not led to believe that those who in this matter still show themselves doubtful, and who wish to appear to be defending Aristotle's [Aristotle] authority against the truth you have demonstrated, truly think this. Rather, I think they are doing this: that, when they have moved every stone and

searched everywhere for whatever might seem to confirm Aristotle's opinion and to undermine or cast doubt on yours, they set these objections before you as if to be tested against the Lydian touchstone — and so they give you occasion, by the Sun of your erudition, to scatter not only every shadow of error but even the slightest little clouds, and to perfect for posterity the most exact doctrine of these matters. And if it is with this intent that they contend with you, then truly I wish them every possible success in this — for they are doing the other thing. Their obstinacy I judge indeed worthy of hatred; yet because by their obstinacy they have wrung from you a benefit shared by all, I embrace them — or rather I bid them not so much fare well as not fare well — no differently than if they had done it with good intent; and I congratulate the literary republic on it.

Concerning the earlier comets, which Regiomontanus [Regiomontanus] and others observed, I await what you are about to publish on the matter any day now; until then I will also suspend my own opinion as to whether absolutely all comets are to be believed ethereal, or whether some part of them is elementary.

To the objections that have hitherto been raised against your new hypotheses, you seem to me to have replied soundly; and I find nothing in them absurd, but rather everything fitting most beautifully together. But whether those hypotheses of yours will perform what is desired of the Copernican [Copernicus] ones — namely, that they present to us the exact positions of the stars for past, present, and future times — that will only then be a matter for judgment, when that greater Work which you are undertaking has come to light. And I do not doubt that in that work you will have compared, with the utmost diligence, the more exact observations of every age — as many as survive — with your own, which I am certainly convinced are most exact, and that you will thereby have constructed this new Machine of the world by a truly divine genius.

Take heart, then, most noble sir, and see to it that we may enjoy your divine discoveries as soon as possible. For even though it is an arduous task — and, as you yourself truly write, the work of many years — I nonetheless hope, indeed I am confident, that you have already toiled through the greatest part of it, and that at this time you are occupied more with collecting and arranging the things you have already established, and with composing tables from them, than with further confirming your discoveries. And since in this you can be greatly helped, in large part, by the labor of your pupils, I beg you again and again not to keep us in suspense too long. From my heart I wish you a life lasting to the years of Nestor; yet you know how deceptive our hopes are, and how often an untimely death befalls divine geniuses especially. So cheat delay, and even by a not-yet-

mature birth bring forth the offspring of your genius to the whole world. If the fates grant you the longer life that we eagerly desire and hope for, you will be able to issue revised editions as well, and at last to satisfy your own judgment too (for as to ours, I have no doubt you will satisfy it fully in the very first edition). Meanwhile you will free us from the perpetual fear that, while you delay too long, we may be cheated of the whole work. For my part I have conceived so great a hope of you and of these hypotheses of yours that I dare affirm for certain that the solid completion of the science of Astronomy is to be expected either from you or from no one. Indeed, since — besides the divine power of your genius — you have been equipped with so many and such great things necessary for this purpose, and have devoted such great expenses, labors, and years to it, there is no one in Europe (and when I say Europe, I mean the whole world) who could be compared to you. Far from here, so help me God, is all flattery — from which both the dignity I hold and the gravity I strive to maintain before everyone will vindicate me, more than abundantly, in the eyes of those who know me and those who do not, and especially of those unacquainted with the fame of my name.

The things you have written, in various places and to various people, about the exact construction and use of the Instruments necessary for observations, have delighted me in the highest degree. For my part, since hitherto I have not been able to satisfy my own self — since I do not allow myself even to look at, much less to possess, instruments that are not exact — I go without absolutely all Instruments, except those acquired merely for pleasure. The Nonnian quadrant [quadrans Nonnianus — Nunes's / Nonius's quadrant] once gave me much anxiety; but because it is most difficult, indeed almost impossible, to construct, I thought about other means, and found various ones — part of which Christophorus Clavius [Christoph Clavius], the distinguished mathematician, published in his little book on describing sundials by an instrument. At last there came into my mind the construction of a certain quadrant, which — because it seemed not inelegant to certain learned men — I have wished to send to you as well. Yet, to confess frankly how the matter stands, and what you yourself most truly affirm: all these inventions have less in reserve than they promise of themselves at first sight. Still, it will be welcome to me to hear your judgment about this last invention of mine. From the little book of N. N., your plagiarist, which he entitled *Fundamentum Astronomicum* [*Astronomical Foundation*], and by its single diagram —

— which he dedicated to Paulus Wittichius [Paul Wittich], I constructed, in days past, when on account of my ill health I could not attend to public business, a new

doctrine of spherical triangles, in which, by means of a table of sines, tangents, and secants, all cases both of right-angled and of oblique-angled triangles are accomplished most easily, without any multiplication or division, by mere addition and subtraction. I would send this too to you, did I not know that you, having merely inspected the one diagram, would easily grasp the whole matter. For from that diagram and from the axiom, already demonstrated by many — that the radius is the mean proportional between the right sine of an arc and the secant of its complement — the whole reckoning is built up.

For what remains: I pray that you fare well, again and again, most noble sir, for many years; and all the offices of love and goodwill that can proceed from me toward you, I offer you most affectionately, earnestly begging that — as you of your own accord began to do — you continue to love me, who love you from my heart. Given at Prague, the 28th of June, in the year 90.

Jacobus Curtius a Senftenau [Jacobus Curtius a Senftenau]

[The following paragraph is Tycho Brahe's editorial note, set in italic:]

Since the description of the Quadrant which he mentions in his letter was attached to it, I am glad to append this here as well — for it is indeed ingenious, and there are others of this kind too. I do not claim that it prevails over the rest of the inventions produced; nevertheless, as Lord Curtius himself frankly admits, subtleties of this kind do not have, in their deeper reserve, what they promise at first sight. In which I subscribe to the things asserted on this same matter in the second Volume of the *Progymnasmata* [*Progymnasmata*], in the earlier part, page 461 [recte: 461]. For besides the fact that these intricate and laborious subdivisions sometimes easily insinuate some hidden flaw, this drawback is also admitted: that certain Quadrants, the closer they are to the center taken, the smaller they turn out, and are therefore less capable of subdivisions; and the Ruler itself, if it does not everywhere exhibit exactly the straight line that passes through, and cut some point in the middle (which is difficult to discern), then one has labored at it in vain — to say nothing of other drawbacks now. For which reason our own method, which is made close to the very limb and circumference of the Quadrant, and does not take up much space, can also be prepared more easily, and is by far more expeditious and more certain — being moreover, of itself, such that the things which can be effected with fewer requisites do not need more. Yet this method of Lord Curtius, ingenious as it is — though not quite suitable enough for practice — it has been permitted to append here, so that its invention may be attributed to that most excellent man, and that no other (as happens) may claim it for himself; and so that I may recall it with grateful mind

to his memory and to the praise of his outstanding genius — or in some such way after his death. Now it is of this kind:

THERE FOLLOWS THE LAYOUT OF THE SUBDIVISIONS

OF THE QUADRANT,

By the most eminent and noble Lord:

CURTIUS [Jacobus Curtius a Senftenau], VICE-CHANCELLOR OF THE EMPIRE,

NOBLY DEVISED.

On a certain quadrant divided most exactly into ninety degrees, let there be described fifty-nine other quadrants. And on the one that next follows the outermost quadrant, let an arc of sixty-one degrees be taken and divided into sixty equal parts; or let an arc of thirty and a half degrees be taken and divided into thirty equal parts; and in either case each of those parts will contain one degree and one minute. Of these parts we use only the first, the rest being omitted as if they were not on the quadrant; and for that reason this division should be done in secret — or, what we would more approve, let this division be made on some other quadrant, and from it let one of those parts be transferred onto the one we have constructed for use, so that the parts to be described afterward may not be confused with the earlier ones.

From the end of this first part, let its semidiameter be transferred onto the quadrant, and let the arc which it subtends be divided into sixty equal parts; and each of these parts will be one degree, or sixty minutes — for the semidiameter of any circle subtends a sixth part of the circle, that is, sixty degrees. Then, from the end of this arc, twenty-eight of these parts are transferred onto the remainder of the quadrant, and they will be equal parts, each one of which we have said contains one degree —

eighty-eight; and if to these you add that first part, which we showed contains one degree and one minute, there arise eighty-nine degrees and one minute. The remaining part, therefore, which is left over up to the end of the quadrant, will contain fifty-nine minutes.

On the next quadrant, which follows this one closely, let an arc of sixty-two degrees be taken and divided into sixty equal parts; or let an arc of thirty-one degrees be divided into thirty equal parts; and each of those parts will contain one degree and two minutes. Of these parts too we use only the first, the rest omitted. From the end of this first part let its semidiameter again be transferred

onto the quadrant, and let the arc which it subtends be divided into sixty equal parts, and let twenty-eight of them be carried over onto the remainder of the quadrant; and we shall again have eighty-eight whole degrees. To these, if we add the first part — which contains one degree and two minutes — there will arise an arc of eighty-nine degrees and two minutes, and that last part, which is left over up to the end of the quadrant, will be of fifty-eight minutes. For the third quadrant we shall take from the beginning an arc of sixty-three degrees, and divide it into sixty equal parts — or half of it into thirty equal parts; and taking from there the first part, the rest omitted, it will contain one degree and three minutes. The rest we shall carry out no differently than was done in the first and second quadrant.

For the fourth quadrant an arc of sixty-four degrees is to be taken; for the fifth, an arc of sixty-five degrees; and so one must proceed, and always for the following quadrant an arc greater by one degree is to be taken, up to the fifty-ninth quadrant, for which an arc of one hundred and nineteen degrees is to be assumed and divided, as before, into sixty equal parts — or an arc of fifty-nine and a half degrees is to be divided into thirty equal parts, and each of those parts will contain one degree and fifty-nine minutes. From the end of this first part, the rest omitted, its semidiameter is again to be transferred onto the quadrant, and the arc subtended by it is to be divided into sixty equal parts, and twenty-eight of them are to be carried over onto the remainder of the quadrant; and we shall again have eighty-eight whole degrees. To these, with the first part added, there arise eighty-nine degrees and fifty-nine minutes, and accordingly the remaining part, which is left over up to the end of the quadrant, will contain one minute. When these quadrants have been divided in this way, let "0" be written against the first quadrant, which we divided into ninety equal parts. For onto whatever part of that quadrant the index-line [linea fiducia] falls, the arc will contain whole degrees precisely and nothing further. To the next quadrant, which follows it, let "1" be written. For onto whatever part of this quadrant the index-line points, it shows one minute. To the following quadrant let "2" be written, and to the one closely following it "3," then "4"; and so we shall proceed up to the innermost quadrant, to which "59" is to be written. For onto whatever of the parts of this innermost quadrant the index-line falls, the arc will contain, beyond the whole degrees, fifty-nine minutes.

This quadrant thus exhibits, in act and in reality, five thousand four hundred parts — that is, all the first minutes which are comprised within ninety degrees; and yet its use is most easy. When the index-line, or the thread of the plumb, falls on some whole part of one of these quadrants, let there always be added to the

whole degrees — which the index-line or the thread of the plumb shows — as many minutes as are written for that quadrant on the side; and there will result the number of degrees and minutes contained in the cut-off arc. For example: let the index-line fall on the forty-fourth part of that quadrant to which, on either side, thirty-five minutes are written. The arc cut off by the index-line will therefore contain forty-four whole degrees, and in addition thirty-five minutes.

Copies of Letters

Of the most distinguished and excellent mathematician, Lord Johannes Antonius Maginus of Padua [Giovanni Antonio Magini], written from Bologna in the same year 1590 to Tycho Brahe in Denmark.

Illustrious Sir,

I received your most learned book, sent to me in your name by a certain studious Dane who was once a member of your household. Nothing more welcome could have been offered to me by you, since I am in the habit of seeking out writings of this kind with the greatest eagerness and of reading them through with the greatest pleasure. Indeed, I could scarcely have hoped by any other route that it would come into my hands, for very few printed volumes of this sort are usually imported into Italy, on account of the great distance of the journey and the difficulty of transport. Added to this is the fact that by so elegant a gift you have made clear in splendid fashion how highly you value me — for which I thank you as much as I possibly can. For what I most desire and habitually strive for is precisely this: that the way be open to me to win the favor of men like yourself. And you, with that singular kindness of yours, have offered me this of your own accord.

I could not, as was fitting and as I had hoped, make my feelings toward you known at once by letter, and the reason was this: I had resolved to send you, along with my own letters, a Work recently composed by me and soon to be published. Last summer, however, when I happened to come upon that studious Dane, I diligently wrote to him by letter, asking him not to refuse, in my name, the requests I shall set down here. I should therefore very much like to have a compendious description of the fixed stars, as they have been corrected by you, so that it may be of use to me in my Ephemerides, which I shall shortly be sending back to press; and in addition, some knowledge of the Eccentricities of the Planets, and likewise of the commensurations of the orbit of each one of them, if you have found these to differ from the Copernican values and have

corrected them. If you will not disdain to gratify me in this, I shall assuredly see to it that you do not regret your kindness toward me. For I have made it my settled practice to praise in my writings, with the candor that befits scholars and professors of the liberal arts, the authors of such achievements as yours.

As for my own opinion and judgment concerning that celebrated work of yours on the Comet observed in the year 1577 — lest you should be left wanting it — take it thus, most distinguished Sir. Since I have perceived your incredible diligence in that matter and your accurate method of observing, I am persuaded that you will be able to correct the motions of the celestial bodies with the utmost exactness, and that by the labor of that work you will most fully satisfy the great zeal and expectation of all, whereby everlasting honor will accrue to your name. I should wish, however, that you would apply yourself most especially to observing and examining the motion of Mars, since it is commonly held that it cannot be observed exactly. And I am of this opinion: that its Eccentricity has changed and that it has a period of its own, so that another equation [aequatio] of the Eccentricity must be introduced into it. Otherwise, if a table be constructed for the greatest Eccentricity, it cannot serve for the least, and conversely. From this we see that Copernicus [Copernicus] — even though he discovered that an Eccentricity of this kind varies — did not on that account compose tables that would suit every period, since the equations of Mars computed for the Eccentricity observed by Copernicus, of parts 5. 51. 30, cannot in the least be fitted to the times of Ptolemy [Ptolemy] himself, for which he defined the Eccentricity of Mars partly at 6.

I cannot but greatly approve the System of the Universe devised by you, although I could wish that the Orb of the Sun and that of Mars did not intersect each other at all. But if, as I have learned from that studious man, Mars at opposition [acronycum] has been observed by you to approach nearer to the Earth than the Sun does, then an intersection of this kind must certainly be admitted. I am in great expectation of observations and speculations of this kind from you, which I shall by no means be ashamed to approve and to follow. And if, in constructing Ephemerides and resolved tables, [the deviation] from the Copernican reckoning, and from the Prutenic tables [tabulae Prutenicae], does not [continues]

[continuation, p. 94] departs even by a fingernail's breadth. I also hope — and earnestly desire it — for that first book of yours on the phenomena of the aetherial world [*De mundi aetherei phaenomenis*], which you promise to publish again, to appear this year. That studious man often told me that you wished to have Werner's [Johannes Werner] book on the motion of the eighth Sphere

[sphaera octava], which, though you have sought it throughout all Germany, you have nevertheless never been able to find. For that reason I have given him one copy of my own, that he might send it to you in my name. If there is anything else I can do for your sake, I shall count it a great honor to have it required of me; I wish you every happiness and the best of fortune in all things.

This year I am to lecture publicly on my hypotheses of the Celestial Orbs [*Coelestium Orbium hypotheses*], which will give me a good opportunity to expound far more fully (as I have already begun to do) what I have published in this field, and to illustrate it with commentaries, geometrical demonstrations, and computations. Before I make these commentaries public, however, I should gladly like to learn and understand your own studies, so that I may also insert and explain your suppositions within them. But lest I become too tiresome to you by excessive length, here I shall make an end of writing, asking you again and again to receive with kindly spirit, and to take in good part, the respect I bear toward you.

Bologna, the Ides of September, 1590.

Most devoted to your illustrious Lordship,

Io. Anton. Maginus Patavinus [Giovanni Antonio Magini].

[Editorial note printed in italic:] *Another letter of the same most learned Magini, prefixed to a certain book which he entitles the* Tetragonic Table [Tabula Tetragonica], *dedicated to me. This book, however, published six years ago, I did not receive when sent by Magini himself; but afterward, found by chance at a bookseller's, one of my students of Astronomy brought it to me.*

To the most illustrious in nobility and most excellent in learning, Tycho Brahe the Dane, Lord of Knudstrup [Knudstrup] and founder of the Castle of Uraniborg [Uraniborg] on the Island Hven [Hven] of the Danish Hellespont — Io. Antonius Maginus Patavinus, Mathematician, sends greetings.

For very many years past I have given much thought, most noble and most learned Sir, to finding an expeditious and easy way by which the square root of any number, however large, might be extracted on the spot. A truly arduous task indeed, and exceedingly difficult — how much I toiled at it, no one will readily believe, save one who has himself at some time made the attempt; and often the difficulty of the undertaking deterred me. But in the end the matter succeeded so happily for me that I found more than I could have hoped. For what I have accomplished in this kind of calculation, you first, most learned Brahe, and then

all the other cultivators of Mathematics into whose hands this shall come, will rightly perceive.

I do not wish here to seem too bold before scholars in praising my own inventions, lest some carping critic [Momus] should cavil that I am too immodest a herald of my own praise. But this work, such as it is, I have wished to dedicate to you — a man of most glorious name, and the most eminent Astronomer of our age — out of gratitude and singular respect toward you, and for the greatest of reasons. For, first, it is you to whom I owe the most: you who so lovingly and graciously opened to me the doors of your friendship, and bestowed upon me more honor than my learning (if any there be), thin and very slight, deserved — when you sent me, through a certain studious Dane, your second book on the more recent Phenomena of the world [*De recentioribus mundi Phaenomenis*], and through the same man asked what I thought of those matters, and most graciously replied to my Letter, discussing many things with me about Astronomical matters. Next, it is you to whom I am most confident this Tetragonic Table of mine will be welcome, because you will be able to use it most happily in eliciting the angles of the inequalities of the planetary motions, and indeed by a readier method than through the tables of Tangents and Secants. Finally, because you are that most excellent Restorer of Astronomy, to whom our age owes much, and all posterity will owe much — since not I alone, but nearly all men of sincere mind have conceived such hope from your Astronomical foundations that they

[continuation, p. 95] eagerly await the restoration of Astronomy from you alone. For you have constructed, with wondrous craft and by the invention of the celestial spheres, such hypotyposes [hypotyposes, "outline-models"] as are well able to preserve the phenomena and the appearances of the heavens, both favorable and adverse, and to define the places of the celestial luminaries for any times whatever — of this there is no doubt. I therefore urge and entreat you, by this small gift offered to you, that what you have so happily begun, and at which you have now been laboring so long in this field of learning, you may at length bring to completion. For no one can perform this more rightly and more happily than you, who by your keen genius were born for the illustration of fallen Astronomy — so I judge, rightly and sincerely, and so all men hope. For if you will share with us, as soon as possible, your most laborious and most excellent Theatre [Theatrum], now completed, you will surely snatch away all glory from those who once attempted the correction of the motions, and from those who now attempt it; and for those who may attempt it hereafter, you will take away every occasion and material.

I know indeed that, after the publication of your labors, my own writings will need correction. But so far is this from troubling me that I rather desire your speculations to be made public as soon as possible — for I shall at once correct my Ephemerides, whose second edition is eagerly awaited, or, if need be, weave others anew. Let me also signify to you, by this letter, that the investigation of the pole at Padua and at Bologna, and the meridian altitudes of Mars and of the fixed stars near it, which you so greatly wished me to observe, I have hitherto omitted. Yet I would not wish to be accused by you on the charge of negligence, since the means of accomplishing this has been snatched from me by the various floods of business that have overwhelmed me, with the added inconvenience of the place, especially at Padua — of which that same man can give you the same testimony.

That Astronomical Sextant which, after your invention and for your sake, I had made at Padua, I have found to answer to the heavens most exactly down to single minutes, since I have detected the very same distances, to a fingernail's breadth, of certain of the fixed stars which you have noted in your catalogue from your own observations. And this I have now carried with me to Bologna, where I shall attempt to complete many observations for your benefit. Moreover, I do not wish this to be hidden from you: that the most noble and most learned man Paulus Bonfilius [Paolo Bonfili], a patrician of Bologna and most devoted to you, has had made at his own expense a Quadrant of wood and metal, ten feet in size, which will display in observations not so much the minutes as the parts of minutes. The same most noble man is eager to have also a Sextant of the same size, with which Instruments, in the topmost tower that he has in his house, we may more conveniently complete celestial observations for your benefit — of all which you shall be informed in due place and time. Here I shall set an end to this letter, earnestly asking you that, if I can be of any use, you make use of me by your own right. Farewell, most renowned Sir, ornament of Astronomers, and continue to perfect Astronomy by your studies and vigils; and the Sparta which you have received, adorn it (as they say), and farewell, again and again, long and happily.

Bologna, the Kalends of February, 1592.

[p. 96]

[Editorial note printed in italic:] *Subjoined to this letter were certain Poems of distinguished men among the Italians; among which the place allows me to add this one of the most excellent Andreas Chioccus [Andrea Chiocco].*

To the most noble and most learned man Tycho Brahe, founder of Uraniborg and Restorer of Astronomy.

When, seized with starry love, you survey round about the swift orbs of the Heavens and the wandering stars, the various courses of the Sun and the labors of the Moon, and the lofty Throne of Jove [Jupiter], and the realms of Venus [Paphian goddess] — and, where the fire of Cyllenian Mercury [Mercury] passes through the contrary orbs, and where it joins all the other lights ever to itself, and gladly shines bright with companion radiance; and where through the aetherial recesses there wander as foes the cold star of Saturn and the star of bristling Mars — not so much, great Brahe, are you seen, keen in mind, to survey the flaming ramparts of the world and to weave together your distinguished work of celestial reckoning upon paper, as to have surveyed in body that immense vastness through the void on high, those Houses [Domus, the celestial mansions], which then with much labor, having searched them out, you lay open from your breast those splendid Doctrines — such as later Descendants shall rise up to honor in a far-off age. Hence you, from your sublime watchtower, an admirer of Olympus, kindle your immortal mind with love of the heavenly Fatherland, and teach men to despise the base earth. Then, leading a life above fate, and above the gifts of those gods, scarcely do mortal things touch you, neither griefs, nor the fleeting monsters of vices.

Be glad of heart, great Brahe — yours it is, who with so great a Hinge [Cardo, the celestial pole] have been able to move a work greater than to cleave with victorious right hand the dense squadrons hurled into battle; or to lead captive Kings beneath your standards, and at once to have joined to a great triumph rich spoils — Barbarian robes gleaming with gold and purple, Mygdonian [Phrygian] bows, quivers, and Lycian arrows; and to enclose, the enemy conquered, with Caucasian soldiery in the harbor — or at least to shut up the foe trembling in farthest Bactra. All these things devouring time scatters into thin air; renowned [deeds, by sleep] are dispersed in [Lethean] forgetfulness. Virtue of the soul alone climbs to the lofty Olympus of the gods, nor does it fear the contagions of cruel Lachesis [Fate].

Andreas Chioccus of Verona [Andrea Chiocco].

ΕΙΣ ΑΥΤΟΝ [Greek: Eis auton, "On the Same Man"]

[Greek epigram — recovered at native resolution (~80–85%); ~10 tokens remain uncertain as to exact lemma/accent and are marked [?]:]

Εὐσαλίας [?] περίων κανόνας, καὶ δαίδαλα κύκλων / Νεύματα ὁ ΒΡΑΑΣ [Brahe] δείκνυσιν ἐμμελέως. / Πλεῖστα μὲν Ἀχαίων ποσιν [?] ἦν πεπονημένα τύπων, / Οὐδεὶς δ᾽ ἐμφανέως πάντα δίδαξεν ὅμως. / Εἰ τοίνυν ἐτεόν τι λέγειν; δέ μις [?] ἐρανώμην [?] / Οἴκησεν τέμενος τέθμια λῷστα μαθών· / Ἢ μᾶλλον στίχες Ἀθανάτων μάλα δεῦρο μολοῦσαι [?] / Μοῦνον ἐπαιδεῦσαι [?] γνήσια ἔργα θεῶν. / Ἀλλὰ διδαξάμενον χθονίοις καλὸν ἄνδρα φθονεῦσαι [?] / Ἕλκειν εἰς ἄστρων ὦκα βόλιορτο [?] χορόν. [Greek: a verse epigram in praise of Brahe — the gist: that Brahe skillfully reveals the canons [?] and the intricate motions of the celestial circles; that much was toiled over by the men of old, yet none taught all so clearly; praising him as having learned the best ordinances, and drawing him into the chorus of the stars.]

Of the Same [Τοῦ Αὐτοῦ — "by the same author"].

[Editorial note printed in italic:] *Since some space still remains in the pages that follow, the Typographer so requesting, I have permitted a little to be subjoined — excerpted from the letters of a certain Doctor of Medicine residing at Padua, written to a studious Dane there for the space of six years.*

Magini stayed here, at Padua and at Venice, for nearly the whole summer. The reason for this is not sufficiently clear.

Meanwhile Galileo of the Galilei, the Florentine [Galileo Galilei], obtained here the Professorship of Mathematics; he began his lectures on the seventh of December. His opening was splendid, before a great throng of hearers. He is generously recommended by Lord Pinellus [Gian Vincenzo Pinelli], who would most gladly, if he could, insinuate himself into the friendship of Lord Tycho. You, who know Tycho's mind, will be able to arrange these matters in whatever way serves the purpose. Magini has lately published a book, to which he gave the title *Tetragonic Table* [*Tabula Tetragonica*], under Tycho's patronage. He has given me a copy to be sent to you, which I shall transmit at the first opportunity. He also reported that the most illustrious Venetians had deliberated, in their council of petitions, to dispatch into Egypt, at a stipend of 300 crowns, some man skilled in Mathematics, who should observe there on Tycho's behalf. So great, indeed, is the celebrity of Tycho here, as great as that of no one of those now living.

Given at Padua, the 28th of December, in the year 1592.

From the letter of that most distinguished man Magini, summarized above, I understand that in Italy too there are certain eminent and outstanding men, devoted to astronomical matters, who likewise procure instruments modeled on ours and do not neglect to carry out subtle observations of the heavenly bodies

with them. This was indeed most welcome news to me. I have no doubt that great benefit to the advancement of the art of astronomy can flow from this — provided that they live under a more upright sphere [in rectiore Sphaera] than we do, are endowed with remarkable skill, and are moreover well supplied with the resources to bear such expenses easily. I would wish that whatever they have so far discovered from the heavens be communicated to me in good time. This, I think, can now be done more conveniently, since I am residing in Germany and at present near Hamburg, a famous trading city which also has extensive commerce with Italy, and am staying in a certain castle of Rantzau [Arce Ranzoviana]. Or even, should I happen later to be elsewhere in Germany, whatever the matter is, it will easily find me.

But above all I have learned that the most illustrious magnates of Venice — as I gathered from the letters I just mentioned — had, a few years ago, with a heroic and generous purpose, resolved that, if this has hitherto been left undone owing to certain intervening delays (as sometimes happens), it should even now be carried into execution. With the most earnest prayers and devoted heart I would long for this: namely, that some young man knowledgeable and skilled in these matters be sent to the city of Egypt formerly called Alexandria, now called Al-Kahira [Cairo]. There, before all else, he would observe most accurately the elevation of the pole, both from the Sun when it is on the very meridian, and from the stars as they cross the meridian, whether toward the south or the north — applying the motion of the Sun as corrected by us and our verification of the fixed stars. This in particular for the following reason: so that it may be established for certain whether the height of the pole, over a long span of ages, wavers somewhat or not — that is, whether the individual horizons of the Earth do not always feel it the same after the lapse of many centuries. Some eminent mathematicians, even among the Italians themselves, suspect this on no slight evidence. So too, the ingenious idea that that great Copernicus [Copernicus] conceived concerning the intricate motion of the Earth's axis, in order to account for the change in the obliquity of the ecliptic [mutationem obliquitatis Eclipticae], might in this way also be in some manner examined. Although — to say what the matter seems to demand — even with the elevation of the pole above any given horizon remaining perpetually exactly the same, this hypothesis can in this respect hold good, provided nothing else stood in the way. But I am not minded to dispute these matters subtly here, nor to interpose my own opinion, since this is not my present undertaking, nor does the place permit it.

These observations I would judge should be carried out and tested chiefly at Alexandria, because it is most highly credible that Ptolemy [Ptolemy], the

principal craftsman in astronomical matters, measured out the latitude of the place where he lived — or, what is the same thing, the elevation of the pole — most exactly long ago, namely about fifteen centuries before now, so that an error of one or another scruple does not lie hidden, since he gives it as 32 degrees, falling short by only two minutes; and certain of his predecessors had also found this. For as to the other inclinations of the pole or of the equator reported by him in his *Geographia*, or elsewhere recorded in writing, these lack exact reliability and were for the most part taken loosely, by estimation. In the same way, with regard to the fixed stars, which for the most part can be seen and observed in some one horizon every year, the diligence that was required in measuring out their longitude and latitude was not applied. A lapse could therefore much more easily have occurred in places of the terrestrial globe not so accessible, and not lending themselves to observation in some one position. Nor, indeed, is it credible that the latitudes which the ancients reported for certain principal cities — investigated from the proportion of the gnomon and its shadow — are correctly determined to the rule, since the tip of the shadow is not sharp enough, and the gnomon would have to be very long [longissimus oportet esse Gnomonem],

most exactly disposed to its own plane, such as it would display in the very minute. I say nothing of the equinoctial moments, around which they for the most part exercised this same practice, since these were not so precisely known to them as this operation requires. And since the Sun changes its declination most rapidly around the equinoxes, it was natural to commit some deviation in this respect, though one not very obvious to the eyes' senses. Therefore, as to what is reported from Pliny [Pliny] concerning the relation of the shadow to the gnomon in the city of Rome — that at the equinoxes it is, as it were, as 8 to 9 — even if this be rightly weighed, and the Sun's semidiameter taken into account, these prove in some measure that the inclination of the world's axis at Rome is now the same as it once was in the times of Pliny, the comparison indeed being made with those measurements which about a hundred years ago were explored there by that most outstanding mathematician Johannes Regiomontanus [Regiomontanus] and may be read. Yet, since a scruple of doubt can still be raised — whether those gnomonic commensurations accepted from antiquity are precise enough — we are scarcely any more certain in these matters than before. I do not now mean to insinuate that Regiomontanus's own determination is itself unstable, to the point that he does not agree with himself within four minutes. Indeed, the very figures he produced he brought forward a little too boldly, from a position of the Sun not sufficiently ascertained, and therefore from a doubtful declination of it — not to add anything about refraction [refractione] and the parallax of the Sun [Parallaxi

Solis], which two he seems to have neglected. By no other means, then — so far as I at least can see — will it be possible to test beyond doubt whether the axis of the revolution of the universe and of the diurnal motion has in any degree altered itself, with respect to a fixed horizon on the Earth, over the several centuries now elapsed, than if at Alexandria above all (as has been said) the elevation of the pole were noted as accurately as possible, and compared with that old Ptolemaic value.

Furthermore, not only would observation newly instituted in Egypt grant this advantage, but also many fixed stars could there, by one and the same effort, be noted from the heavens — stars which in our horizons never rise, right down to Canopus itself. In the Sun too, and the Moon, and the rest of the planets, very many things could there be explored that bear most subtly upon investigating both refractions and other matters according to their standard. By these the observations of the ancients who lived there could be set within limits, and at the same time examined together with those which have been ascertained in these northern regions — namely, to what extent they agree with them or not. Moreover, many further aids to the restoration of astronomy in its entirety [Astronomiae in integrum restituendae] would come from this — to enumerate all of which one by one would be too long.

You therefore, most illustrious and most powerful Venetians, if you do not think it beneath you to bestow upon this matter that excellent care, so worthy of praise — as your splendid intention previously became known to me — you will indeed accomplish a thing not only useful, and long desired in vain, but also worthy, for all posterity, of the memory of your renowned glory, which otherwise shines far and wide.

For my part, so far as in me lies, I would lend even helping hands to this undertaking — whether by arranging the implements and means, or by prescribing what ought to be done — and shall in no way fail you in my duty, which with all deference I ever reverently offer you. Although I do not deny that there are to be found in Italy, and indeed in your own renowned city, men who could perform these very things, and others pertaining to this, far more readily than I. For Maros will not be wanting, where there are Maecenases [Maecenates].

APPENDIX

ON ARCHITECTURAL STRUCTURES SUITED TO ASTRONOMICAL OBSERVATIONS

[DE ARCHITECTONICIS STRUCTURIS ASTRONOMICIS OBSERVATIONIBUS ACCOMMODIS]

The accounts of the astronomical instruments, set out in this manner (as has been seen above), sufficiently and abundantly treat the mechanical part of the art — which ought to be the first of all, and without which everything else is attempted in vain — and suffice, with a variety and abundance not merely pleasant but also useful and almost necessary, for every kind of use. But if these instruments are to be applied to their exercise, and to the office for which they are destined, fittingly and without inconvenience, there is required not only a suitable place, but also opportune buildings, in which this practice may be administered without difficulty or any disturbances.

The PLACE should above all be elevated, so that the horizon may be viewed freely on every side, with nothing obstructing — no woods or mountains or other buildings. It is also helpful that the same place be solitary, and removed from the noise of the crowd, so that one may enjoy philosophical leisure — yet in such a way that necessary supplies are at hand, and access lies open from time to time to the learned and the discerning, while the common crowd is kept away, as people who neither grasp such things nor value them as they deserve. And although the places that lie in the southern region of the lands might seem preferable — on account of the more upright position of the sphere, and perhaps more frequent clear skies — to those that incline toward the poles and are more northerly, in this northern situation of ours; nevertheless, since it is not opportune for everyone to change his homeland or the place where he lives for that reason, nor is the condition and convenience that is sought granted in just any of the more southerly parts of the Earth — especially unknown and foreign ones — one must be content with it, and constantly and diligently overcome, by occasion of place and time as it offers itself and is at hand, the difficulties and inconveniences, if any arise, lest the same befall as Seneca [Seneca] truly says about time: "We have little, but we waste much." In Egypt, indeed, and in other places of Africa and Asia, where the ancient astronomers lived, this would be granted more readily, on account of the sky being (as they say) more cloudless, and the sphere less inclined. But since Bellona [war] has driven out nearly all the liberal arts throughout the Turkish empire, it is likely that astronomy is in exile there, or held

in less esteem (except insofar as it is perhaps still in some manner practiced by the Arabs). As for other parts of Europe that incline toward the south, better things would indeed be to be hoped, insofar as the Turk or the Muscovite does not lay them waste — provided that they do not there turn away from the liberal arts. But since those kingdoms too are for the most part occupied with other things, and care less for astronomy (so far at least as is known), it seems that one would make loss rather than gain who should prefer those parts, however more southerly, to those which incline somewhat toward the north. Indeed, since observations are accomplished more conveniently and more fully in winter, when the nights are longer, the northern region [Arctoa ora] has this prerogative: that it not only affords this, but moreover, by its own frost — especially when the north winds [Boreales venti] blow — so purifies and thins the air that for many continuous days in succession it is often most clear, so that the stars shine and twinkle at night as brightly as possible; whereas in the more southerly regions it then very frequently either rains, or the sky is otherwise overcast with clouds and damp, and less open to the contemplation of the heavenly bodies.

Prince William, Landgrave of Hesse [Princeps Gulielmus, Hassiae Landgravius], of most praised memory — earnestly devoted to astronomical matters, and not slightly imbued with them — indeed wished that I would choose my place of habitation in a more southerly region, that I might watch the heavens with greater convenience, as is clear from certain of his letters to me printed in the first volume of the *Astronomical Letters [Epistolarum Astronomicarum Tomo primo], page 21*; and there is no doubt that he did this with the best intention — and perhaps also to entice me there to him. But I, for my part, judge that in Denmark no fewer reliable observations can be obtained than in Hesse, or in any other part of Germany (to say nothing now of the other kingdoms of Europe), except that some stars rise in the more southerly regions which in the north remain perpetually hidden. This, however, is of no great moment, nor does it much conduce to the restoration of astronomy. My one-and-twenty books of manuscripts, which are in my keeping, embracing the most accurate observations of as many years carried out in Denmark, will be able to attest this — observations such as can scarcely be shown to have been obtained anywhere else, however in a more meridional region (let it be said without envy), in the meantime. In these, not only are the places and vicissitudes of all the planets, year by year — and not even Mercury, which more rarely appears at any considerable elongation from the Sun — repeatedly and in manifold ways explored; but also the positions of the fixed stars, as many as are in any way visible, are noted most subtly. And afterward they are entered from this into a canonical description [Canonica descriptione], such as no one has been found

hitherto to have furnished — not even any of those who once inhabited Egypt and Australia [the south], and (as is thought) more serene regions of the lands — nor any of their successors, wherever in the world they have lived. This I shall publicly make plain, God willing, before long — declaring it not out of any arrogance or contempt of the ancients, but because the truth of the matter so attests.

And let this much, concerning the choice of place (in which, however, I allow everyone to abound in his own opinion), have been enough to advise.

The occasion itself will easily suggest more. And if not everything can be had as one would wish, the convenience that is offered must nonetheless be accepted, whatever it be — so that something rather than nothing may be accomplished.

The BUILDINGS, furthermore, are to be erected in such a way that they serve observations conveniently, and that they hold the several instruments firmly, rightly, and suitably arranged in keeping with their size and form; that they keep them whole and unharmed from the injury of the air, the winds, and the rains; and that, at the same time, coverings be constructed above the instruments themselves, so that these may, when the matter requires, be opened with slight effort and closed again. The material of the structures must be entirely of stone — whether of baked bricks [coctis lateribus], or of some other quarried stone — and, where there is need, the instruments must for the sake of firmness be supported on columns, whether of marble or otherwise of rock, and all fixed in firm ground, lest they wobble in any way, or contract over time any degree of instability. The coverings, however, should be made of some lighter framework, so that they may more easily be opened and put together again. There must also be dwellings and heated rooms [vaporaria] for those observers who keep watch over such matters. And both these and the other requisites ought to be so neatly arranged that no annoyances, no difficulties or inconveniences, may retard the work itself or render it tedious.

Anyone, however, for whom funds are available, can according to his own judgment devise and construct one form of building after another of those bearing on this purpose — according to the suitability of the place, and the configuration and supply of the instruments. On this matter, then, I think nothing in particular should be prescribed to anyone. Yet if it should be desired to know this plan, which we ourselves chose and carried out in these architectural works — accomplished with no small labor and expense on that island of the Danish strait [Insula freti Danici], famous for shipping, called Venusia (in the common tongue Hven [Huena]), and begun twenty-two years ago — we shall give that too,

so that it may be evident together in what places and in what forms of structures those instruments, whose representation and description we have presented before, were arranged. From this each person may then draw whatever he wishes, and accommodate it to his own uses. For I hope there will in time be some whom so lofty a care touches, who may strive to imitate, or even to surpass, these things with great endeavors.

Diagram. Engraved bird's-eye ground plan of the whole Uraniborg complex on Hven. The engraving is set within a ruled rectangular border, headed by a decorative ribbon ornament and closed at the foot by a foliate ornamental band. The title is engraved across the top:

> **ARCIS VRANIBVRGI QVO AD TOTAM CAPACITATEM DESIGNATIO.**
> [Plan of Uraniborg Castle, as laid out to its full extent.]

The plan shows the square rampart enclosure, its corners pointing to the four world-quarters (a diamond orientation on the page), with the semicircular re-entrant bulges (bastion-like rounded projections) at the midpoint of each side. At the center sits the round garden plot enclosing the main house. The legend letters are placed across the plan:

- A (center): the main house, set in the round central plot.
- B (left/west corner): one of the corner points of the rampart, with a small tower-pavilion.
- C (right/east corner): the corresponding corner point with its tower-pavilion.
- D (top/north corner): the gate/corner with its gatehouse tower.
- (bottom/south corner): the corresponding gate/corner with its tower (the south point).
- N (on the avenues running from center to gates): the four avenues toward the gates and the gatehouses.
- O (near the center): the four garden entrances.
- M (in the semicircular ramparts): the arbors/bowers set in the semicircular ramparts.
- L (within the garden quarters): the herb and flower gardens.
- H (within the outer quarters): the tree gardens.
- F (near a domed pavilion, lower left): the inner form of the rampart.
- G (lower left, along the rampart): the outer form of the rampart with its layout.
- I (flanking the central house): [the central plot / house surroundings].

At the lower right, outside the plate frame, the catchword **DELI** is engraved (catching the next page's heading *DELINEATIONIS*).

DELINEATIONIS ARCIS VRANIBVRGI, QVO AD TOTAM CAPACITATEM EXPLICATIO.

[Explanation of the Plan of Uraniborg Castle, as laid out to its full extent.]

Frederick II [Frederick II of Denmark], of ever-glorious memory, King of Denmark and Norway, etc.—second to none in virtue, magnanimity, and integrity—departed this life ten years ago, to the immense grief not only of Denmark and its subjects but also of the neighboring lands, in the fifty-fourth year of his age. He was surely worthy of a longer life, had it so pleased God to grant it to him. This best of kings, besides his other heroic gifts, was truly generous and open-handed toward the liberal studies. He understood that astronomy holds the foremost place among these, that it has always been held in the highest esteem by the greatest monarchs and kings, that many of them have won praise from its cultivation, and that not the least lasting renown has thereby been won. He therefore judged it well worth his while that this science too should be splendidly cultivated and fostered in his own kingdom.

For this reason, when he perceived that I had been devoting my efforts to its restoration, and that I had spent many years in that arena since my youth—so that, in order to continue this work and bring my adopted purpose to its goal, I had resolved to leave my homeland and withdraw into Germany, where I might pursue it more peacefully and conveniently—he summoned me, and with gracious kindness urged me to carry out the same in Denmark. He of his own accord offered me, and bestowed by royal favor, the island of Venusia in the famous Danish Sound—commonly called Hven [Hven]—as a place suited and convenient for my celestial studies and labors. I am accustomed to recall the memory and remembrance of this never-sufficiently-praised king's counsel on other occasions as well, since he deserved so excellently not only of me but of the whole science of astronomy by this act. Therefore all posterity—to whom, as I hope, the use and fruit of this matter will one day come—ought with grateful mind to celebrate the name of that most serene and excellent king.

By the decree, then, and the gracious will of that most excellent king, since buildings suited to the astronomical undertaking were to be solidly and magnificently erected for me on the said island, I chose the most elevated spot in

it (for the whole island stands rather high of itself), near as it were its very middle. There I undertook to build, from the foundations up, the castle named from the very heavens whose observations it was to serve, and for that reason called Uraniborg [Uraniborg]. I began in the year 1576 and completed it in the following years. Its orthography [orthographia] you see here represented according to its whole form and extent, so far as could be done on a flat surface. The particular features that need to be set forth in this delineation are as follows —as far as the letters noted at the several places allow each to be indicated:

A. The principal house, built in the very middle of the whole enclosure, forming a perfect square by its four equal sides, and oriented most exactly to the four quarters of the world, so that two of its turrets face south and north, while both gateways look precisely east and west.

E. The eastern gate, composed in rustic and Tuscan work.

D. The western gate, wrought in the same work. These two gates had above them, in a suitable little house, two large English mastiffs as watchdogs, so that by their barking they might signal those arriving from either side.

S. The printing-house [officina typographica], in a small form somewhat resembling the larger house in its façade.

C. The little house for the servants, likewise representing the larger house in its frontispiece and certain other features.

F. The inner facing of the rampart.

G. Its outer form, with its own arrangement.

N. The four avenues leading toward both gates and toward each little house, which run out exactly to the four quarters of the world.

O. The four garden gates.

M. The four arbors set, for the sake of pleasantness, in those semicircular ramparts.

L. The gardens of herbs and flowers.

H. The gardens of trees of various kinds, about three hundred in number, etc.

And this is the description of the whole enclosure. The circuit of the rampart has a square figure, interwoven in the middle of each side with a semicircle, as appears in the preceding plan. Each side of the square contains 500 feet [pedes

500]. The thickness of the foundational rampart is twenty feet [pedum viginti]. Its height is 22 feet [22 pedum]. The diameter of the interior semicircular rampart is about ninety feet [pedum circiter nonaginta]. The house itself, set in the middle—which, as I said, is also exactly square—has on each side about 60 feet [pedes circiter 60]. The height of the wall is 45 feet [45 pedum]. The round towers set on the south and north sides have 22 feet [22 pedes] in diameter, to which the surrounding galleries adjoining on the outside add 10 feet [pedes 10]. The porticoes on the lower part of the square, to east and west, have 15 feet [15 pedes] on each side. The whole height of the house, from the surface of the ground up to the topmost Pegasus, is 75 feet [pedum 75]. The house likewise, on every side, has underground structures [hypogaea aedificia], the depth of which is 12 feet [pedum 12]—indeed there are also certain other things below these. But since these are subterranean, they are not represented here, although they consist of many distinctions and are arranged for various uses; they too were accomplished at great expense—almost no less than the upper part of the house, which stands above the level of the ground and lies open to the sky.

I now subjoin the fuller delineation and exposition of the principal house, situated in the middle, so that everything may appear more distinctly. There I shall also display some of the subterranean and crypt-like [cryptica] parts, so far as can be done, and insofar as it is granted to imitate such things on a flat surface. For everything built here—not only below but also above—is so manifold that one could hardly believe this single house could contain such and so many things; and to recount them would be too lengthy, and perhaps to some tedious.

> Sacred house of Urania [Urania], renowned watchtower of heaven,
> Founded on a lofty site and made firm with ramparts, Surrounded by
> your trees and herbs in gardens, You who through thrice-seven years
> have surveyed all the stars, Lifting your august head to high Olympus: Do
> you now lie thus despised, and now bereft, at rest? Perhaps this is a
> matter for laughter to those above, whose care is heavenly: Lest great
> gifts be wrung from us paltry mortals. So roll on and shift the turns of all
> earthly things. Let it be praise enough for you alone, who once turned
> heaven and the stars.

Diagram. Engraved plate combining a sectional/elevation view (orthographia) of the principal house of Uraniborg above, and its ground plan (ichnographia) with explanatory legend below. The headings are engraved across the top:

> **ORTHOGRAPHIA PRAECIPVAE DOMVS ARCIS VRANIBVRGI IN INSVLA PORTHMI DANICI VENVSIA Vulgo HVENNA, ASTRONOMIAE**

> **INSTAVRANDAE GRATIA CIRCA ANNVM 1580, a TYCHONE BRAHE EXAEDIFICATAE.** [Elevation of the principal house of Uraniborg Castle, on the island of the Danish Sound, Venusia—commonly Hven—built by Tycho Brahe around the year 1580 for the sake of the restoration of astronomy.]

A second engraved heading repeats the title in two columns flanking the central spire:

> (left) **ORTHOGRAPHIA PRAECIPVAE DOMVS INSVLA PORTHMI DANICI de gratia circa annum 1580 exaedi-** | (right) **ARCIS VRANIBVRGI IN HVENNA Astronomia instauran- a TYCHONE BRAHE situata**

Upper portion — the elevation/section (orthographia): A symmetrical multi-storey building crowned by a tall central onion-domed cupola with a finial, flanked by smaller corner cupola-towers. The cutaway shows the vaulted observatory galleries and the central rooms. Letters placed on the elevation:

- N (far left, corner tower roof): corner pavilion (west/north corner observatory tower).
- S (far right, corner tower roof): corner pavilion (corresponding tower).
- O (upper left, on the observatory level): the larger southern observatory [Observatorium maius Meridionale].
- R (upper right): the larger northern observatory [Observatorium maius Septentrionale].
- M (left, mid-level): the museum / library wing.
- E (left-center): a chamber (Camera Caerulea / blue chamber level).
- D (right-center): a chamber.
- A (center, ground level): the eastern gate / main entrance.
- B (left of center, ground): the winter dining room.
- C (right of center): a guest chamber.
- F (lower left): the foundational corner-stone position.
- L, K, H, Z (lower levels, left and right): the kitchen, cemented well, stairs, and adjoining service rooms.
- X, X (flanking the central drum): structures with carved images.
- Numbered vault marks (lower section): the vaulted cellars and subterranean spaces (figures 1–9 distributed across the cutaway).

Lower portion — the ground plan with legend (ICHNOGRAPHIA ET EIVS EXPLICATIO): Below the elevation is engraved the floor-plan of the house within its round plot, headed:

> **ICHNOGRAPHIA ET EIVS EXPLICATIO** [Ground plan and its explanation.]

The legend is engraved in two columns flanking the plan. As engraved (verbatim, with abbreviations expanded where legible):

Left column:

> A. The eastern entrance [Ianua Orientalis]. C, [the western, Occidentalis,] the right angles meeting, so that the winter dining room or hypocaust [Cænaculum hybernum sive hypocaustum] [...], in its angle behind the small furnace [paruú[?]], might be a spagyric [chemical] laboratory, in which that [larger furnace] more readily [operi[?]] descended to hand for this work [...]; turning [a table/wheel], which distributes the waters this way and that. D. That winter dining room [Cænaculum illud hybernum... by steps/gradibus]. L. The steps for the ascent into the kitchen [Gradus pro ascensu in Coquinam]. K. The cemented well [Puteus cæmentitius], serving the hydraulic [device], and distributing the waters carried through the wall into the several lower [chambers]. P. The steps [Gradus[?] — caption tail illegible]

Right column:

> [...] western [occidentalis]. ⊙. Passage 4, at the corners [Transitus 4 ad angulos[?]], which afterwards were reduced into three, [...] so that the dining room D might be enlarged, and [made] into a certain secret laboratory [...]; five distinct furnaces there were, which served the fire-master [Pyronomicus], lest [the fire] ever [fail]. B. The fountain of the aquarium, revolving [Fons æquarium volubilis[?]], which, when desired, threw [the waters] up on high. E, F, G. Chambers for guests [Cameræ pro hospitibus] [...] the upper storey. H. 40 ells deep [40 ulnas profundas], by a device through siphons secretly this way and that [...] the chambers both upper and lower [...] for the descent into the chemical laboratory [Chymicum] [...]

Lower (across both columns):

> [...] [Pyronomicum]. T. The library [Bibliotheca]. VV. The great globe of orichalcum [Globus magnus Orichalcicus], shown by number. V. The four

> tables for the students [Quatuor Mensæ pro Studiosis]. 4. The chimneys [Camini] both ascending from the lower laboratory, and in the four corners of the rooms. Y. The beds [Lecti] in those same rooms, disposed here and there. The rest the careful inspector of the house depicted above will be able to square [with it]; though here, for the sake of the cramped space, they are shown as it were in a doubled, almost smaller, form.

The ground-plan figure shows a square house with rounded projecting towers (north and south) and porticoes (east and west) within a round/oval plot. Interior letters legible on the plan include A, B, C, D, E, F, G, H, K, L, M, P, T, V (with numbered marks 1–9), and W at the western tower. Recovered key captions: A Ianua Orientalis; B Fons æquarium volubilis[?]; C [Ianua] Occidentalis; D Cænaculum hybernum; E, F, G Cameræ pro hospitibus; H the 40-ell shaft [40 ulnas profundas]; K Puteus cæmentitius; L Gradus pro ascensu in Coquinam; P Gradus[?]; T Bibliotheca; V Quatuor Mensæ pro Studiosis; VV Globus magnus Orichalcicus; Y Lecti; ⊙ the four corner passages [Transitus 4 ad angulos].

EXPLICATIO PARTIVM MAIORIS ET PRAECIPVAE DOMVS.

[Explanation of the parts of the larger and principal house.]

This larger and principal house of Uraniborg began to be built around the year 1576 [Anno 1576]. Its first foundation-stone was laid—at that time, for many years, the magnificent legate to Denmark of the most serene and most powerful King of the French, the lord Charles de Dançay [Carolus Danzaeus] of Aquitaine, a man second to none in integrity, virtue, and practical experience, and moreover excellently versed in the liberal arts. Since he pursued me with a singular and constant affection, as long as he lived—for he died nearly ten years ago, in the eighty-first year of his age—he always greatly favored me and my affairs. And as soon as he learned that this house was to be built, he of his own accord pledged that he would lay the first cornerstone here. Presently he had the following words inscribed on a certain block of porphyry:

> **REGNANTE IN DANIA FRIDERICO II.** CAROLVS DANZAEVS AQVITANVS. R. G. I. D. L. DOMVI HVIC, PHILOSOPHIAE INPRIMISQVE ASTRORVM CONTEMPLATIONI REGIS DE- CRETO A NOBILI VIRO TYCHONE BRAHE

DE KNVDSTRVP EXTRVCTAE VOTIVVM HVNC LAPIDEM MEMORIAE ET FELICIS AVSPICII ERGO P. ANNO ↀ IↃↃ. LXXVI. VI. ID. AVGVSTI.

[In the reign of Frederick II in Denmark. Charles de Dançay of Aquitaine, R. G. I. D. L. [royal counselor/legate, etc. — abbreviation], to this house—built by the king's decree by the noble man Tycho Brahe of Knudstrup for philosophy and above all for the contemplation of the stars—set up this votive stone for the sake of memory and of a happy beginning. In the year 1576, on the sixth day before the Ides of August (i.e., 8 August).]

When the day appointed for the foundation drew near, that excellent Dançay arrived, accompanied by some noblemen and also by some learned friends from among my acquaintances who were to be present at this act. On the eighth day of August, in the morning, with the Sun rising in the east together with the Heart [of the Lion, cor ♌ — Regulus], and the Moon occupying the western cardine in Aquarius [♒], in the presence of us all he laid the same stone, having first propitiated the sun with various wines, and praying for good fortune, with the friends who stood around joining their good wishes. This stone was set in the eastern angle of the house toward the south [versus Notapeliotem, i.e., the south-east], as is shown in the accompanying figure at the letter F. Afterward the whole house began to be erected, and in successive years was completed—though not a few, nor slight, difficulties and delays meanwhile crept in, of which it is not relevant to speak.

The explanation of the orthography of the same house, here assigned, is as follows:

A. The eastern entrance [Ianua Orientalis], composed of Ionic and Doric work.

B. The winter dining room [Coenaculum hibernum].

F. That foundational stone, of which I made mention, which the legate of France laid on the seventh day [recte: 8 August].

G and H. The windows of the subterranean cells.

C. The chamber for guests. There are likewise two similar ones toward the west.

M. The museum [Musaeum] with its library.

I. The chemical laboratory [Laboratorium chymicum], subterranean and round, containing 16 various furnaces destined for the spagyric art [Ars Spagyrica].

[A foramen / opening] through which charcoal is sent down for the pyronomic [fire] labors.

Z. The subterranean cellar for storing wood.

q. The kitchen [Coquina].

D. The chamber called the red [Camera rubea]. α. The yellow octagonal chamber [Camera flava octogonalis]. E. The blue chamber [Camera Caerulea].

Corresponding to these three toward the west [...]. The summer dining room [Coenaculum aestivum] of a green color, and in its paneling adorned with pictures of the principal herbs; from which a great number of ships—especially in summer, sailing past in front—is pleasantly viewed.

X. The windows of the upper storey.

O. The larger southern observatory [Observatorium maius Meridionale], containing several distinguished and larger astronomical machines—especially the Azimuthal Semicircle [Semicirculus Azimuthalis], the Ptolemaic Rules [Regulae Ptolemaicae], the brass Sextant [Sextans Orichalcicus] for taking altitudes, and the medium-sized brass Azimuthal Quadrant [Quadrans Orichalcicus mediocris Azimuthalis]—which in their place above have been both represented and expounded, namely instruments by number 8, 9, 4, 3, retaining of course the same order in which the instruments are here recounted. (And this is to be understood also in what follows, where need be.)

P. A certain globe, upon which is set an instrument for observing the distances of stars, so placed that it may be revolved on it to all quarters—such as is also depicted above under the Sextant, number 16. To this one toward the west there corresponds a similar one.

Q. The octagonal circuit [Ambitus Octogonalis], in which is situated the aforesaid globe.

N. The smaller southern observatory [Observatorium minus Meridionale], holding the brass Equatorial Armillae [Armillae Aequatoriae], number 15.

VV. The descent into the laboratory and the ascent into the observatory.

R. The larger northern observatory [Observatorium maius Septentrionale], also filled with several great instruments—namely the larger brass Rules or Parallactic [Instrument] [Parallaticum maius Orichalcicum], which by the circumference of the wall could also show the azimuth, number 10, laid out

plainly. There was also in the same tower a Sextant for a single observer giving distances; and that bipartite Arc [Arcus bipartitus]; and that instrument which was once in use for observing the new star [the nova of 1572]—which three are set forth above under the numbers 17 and 15. There was also kept there a certain wooden Parallactic [instrument], which had been in use with that great Copernicus [Copernicus] and was sent to me from Warmia [Warmia]—of which I made mention in its place.

S. The smaller northern observatory [Observatorium minus Septentrionale], containing other Equatorial Armillae, number [...] delineated.

T. Another globe, similar to the former, to be set in place of a support, serving the Sextants; to which likewise one toward the west corresponds.

In the upper part of the house itself, where round windows are seen, there are eight little chambers for the students. The topmost octagonal chamber, just below the summit of the house, from which there is a view on all sides, has around its circuit a gallery [ambitum quem Galleriam vocant] above the roof itself.

φ. The octagonal structures [Structurae Octogonales], in which are seen carved images representing the four parts of the year [the four seasons].

6, 8. Seven chimneys [Septem Camini] ending in one toward the south, and another seven toward the north, so that all the chimneys of the whole house meet distinctly in two places.

N. The clock [Horologium], whose bell [campana] hangs above.

A. The gilded Pegasus [Pegasus auratus], which, turning by its pointer, shows below the topmost paneling of the highest chamber, from where the wind blows; and there another pointer, revolving on the same hinge, indicates the hours.

Such is the exterior face of the house, whether viewed from the east or from the west; and if one compares the southern part with the northern, he will find the same form, so that everything corresponds mutually to itself and presents a fitting symmetry—as is required in architectural works, if they are to be made skillfully and in due manner.

Moreover, the subterranean parts, which are seen below marked with dotted lines, are to be taken thus: whatever is seen beneath the southern tower expresses, as far as could be done, the pyronomic [fire] laboratory, where: 1. There is a round table set in its very middle, on which are placed the things to be prepared. 2. The number represents furnaces of various kinds disposed all

around, as best they could be. And there were, by number, 16 [num. 16]. 3. Three baths of different kinds; one digestory in ashes; four large athanors; two small ones; two distilling furnaces in sand or ashes; one for a large vessel, fitted with double channels; another secret furnace with lamps; two reverberatory furnaces, one of which reverberated in a straight line, the other along a helical line, both openly and closed. And the greater part of the furnaces was of fusible stones brought from Norway, which they call Bergen stones [Bergenses]—since these withstand the strongest fire and can be skillfully worked. But if every single thing that was in this laboratory had to be set forth, it could not be accomplished in few words.

The things marked below the larger house itself indicate the cellars, store-rooms, and pantry, subterranean—where: the doors through which there is entrance this way and that, number 3. The columns set in place of supports are marked number 4. Beneath the northern tower, beside number 3, that cemented well [Puteus cementitius] is seen, 40 ells deep [40 ulnas profundus], of which there is further mention afterward in the ground plan, under number 6. There are cemented vaults [Cellae Cementitiae], in which certain foodstuffs are kept [...]. The rest the figure partly expresses, partly leaves to be understood.

Stjerneborg (the Star-Castle outside Uraniborg)

Diagram. Elevation (orthographia) of Stjerneborg [Stellaeburgum], the underground star-castle situated outside the castle of Urania (Uraniborg). The engraving shows a perspective cutaway of the walled, partly sunken enclosure: the instrument crypts appear as rounded mounded domes set into the ground inside a ring wall, with the principal large dome (lettered **C**) rising at the center, surmounted by a tall finial. Lower, foreground crypt-cupolas are opened to reveal the instruments beneath; small attendant figures and an observer at a triangular-framed instrument appear at right. The enclosing wall runs around the whole plot. Visible key-letters on the elevation:

- C (center, principal large dome)
- E (left-foreground cupola)
- N (left-foreground, below E)
- F (cupola left of center, with radial spoked figure)
- K (right, on the wall — a globe on a stand)
- L (far left, on the wall — a globe/figure on a stand)
- H (foreground, central column base)

- D (small object, right of center foreground)

[Several smaller foreground objects and the figures at the right-hand instrument carry no legible letters.]

Title (engraved, verbatim): **ORTHOGRAPHIA STELLÆBVRGI EXTRA ARCEM VRANIÆ SITI.** — "Elevation of Stjerneborg, situated outside the castle of Urania."

Diagram. Ground plan (ichnographia) of Stjerneborg. The plan is a square enclosure with semicircular niches (apses) projecting from the middle of each of the four sides, giving a quatrefoil silhouette. At the center are the circular instrument crypts, each drawn as a set of concentric rings (the stepped sunken pits) and lettered. A central rectangular hypocaust block (**B**) sits among them; a stair/passage runs down from the south portal (**A**) at the bottom. Key-letters as placed on the plan:

- A (bottom center): the portal / descent into the crypts
- B (center): the square hypocaust
- C (upper center, largest concentric crypt): crypt for the great equatorial armillae
- F (right of center): crypt
- G (left of center): crypt
- D (lower left, concentric crypt)
- E (lower right, concentric crypt)
- S (center, on the stair from A): start of the subterranean passage
- O (small chamber left of B); Q (small chamber right of B); V (small chamber, between B and Q)
- M (top center, in the north apse): round stone table
- I / I (left apse, marked with both a circle ⊙I and a square ■I)
- H / H (right apse, marked with both a circle ⊙H and a square ■H)
- L (lower left corner, a small circle); N (lower right corner, a small circle)

Title (engraved, verbatim): **ICHNOGRAPHIA STELLÆBVRGI.** — "Ground plan of Stjerneborg."

Explanation of Stjerneborg [STELLÆBVRGI EXPLICATIO]

The towers built in the principal house of the castle itself, toward the south and the north, together with their projecting wings projecting here and there, were sufficient for housing not a few instruments, however large. Yet since over time, for certain good reasons, I arranged to have still more instruments made, and

these could not be accommodated suitably enough within those spaces — so that each one's particular use might be assured without obstruction from another — I afterwards, around the year 1584, on a certain hill outside the castle toward the south, about 70 lesser paces distant from the outer rampart, had a certain underground observatory built, with various crypts constructed of solid masonry from bottom to top, at no small labor and expense. This was partly so that I might set up some of my chief instruments there firmly and securely, lest they be disturbed in any way by any winds, and so that they might serve their use more conveniently; and partly so that I might separate my students from one another, since several were in attendance, and might assign some of them to carry out their observations in the castle itself and others in these crypts — so that they would not be a hindrance to one another, nor compare their observations among themselves before I wished.

I named this observatory in the Danish tongue **Stiernborg** [Margin/inline gloss: in the source the Danish is set in Fraktur], which is nearly the same in German, and which in Latin sounds as **Stellaeburgum** [the "star-castle"]. Here you see its form and elevation, together with its ground plan. A brief account of these follows.

A. The portal, composed in the Ionic order, through which the descent into the crypts of this observatory is made. Above it has three crowned lions, skillfully carved, and on either side porphyry stones bearing fitting inscriptions — inscriptions which are set out in the first book of the *Astronomical Letters* [*Epistolae Astronomicae* I], in the place where this cryptic observatory is discussed. It would be too long to repeat them here; the latter one, however, which is more universal, I shall give shortly. **B.** A round vaulted chamber, beneath which is a hypocaust, into which there is access on every side from the crypts. **C.** The crypt for the great equatorial armillae described under no. 14. **D.** The crypt for the great revolving quadrant, called no. 6, set out earlier. **E.** The crypt for the zodiacal armillae explained under no. 11. **F.** The crypt for the great geometric square containing a steel quadrant within, marked no. 7. **G.** The crypt for the four-cubit sextant on its support and revolving globe, which is represented by no. 16. These matters, as far as the crypts themselves, are briefly indicated.

The inscription of which I spoke — on the other side of the portal, toward the south, marked out in gilded letters on porphyry stone — is this:

> **D. O. M. AND TO POSTERITY, SACRED.** [D. O. M. POSTERITATIQVE SACRVM.]

> Observing that ASTRONOMY — the most ancient and most excellent of the sciences — though long and greatly cultivated, was nevertheless not yet sufficiently soundly established, nor vindicated from its errors, he, for the restoring and perfecting of it, devised and constructed various and exact instruments, sufficient for observations of the celestial bodies of every kind, with incredible labor, diligence, and expense. These he disposed partly in the castle URANIBORG, built nearby for the same purpose, and partly in these crypts, for a more constant and more convenient use. And commending, dedicating, and consecrating this most rare and most precious treasure to you, O illustrious posterity of every age to come, [he asks] that — for the glory of the eternal GOD, the maker of the admirable celestial machine, and for the propagation of the divine art, and for the honor of his fatherland — you preserve it forever, and let it not be impaired by age or by any other harm, nor transferred elsewhere, nor in any way whatsoever violated; if for no other reason, then out of reverence for the watchful eye of the author of the universe.
>
> He who both began and completed all these things on this island, having set up this monument, asks and entreats you. **TYCHO BRAHE, son of Otto** [TYCHO BRAHE O. F.] **HAIL, YOU WHO READ AND DO THESE THINGS, AND FAREWELL.** [HAVE QVI HÆC LEGIS FACISQVE, ET VALE.]

Outside, in the open area of this Stjerneborg enclosure, are the stone columns **H, I**, arranged on both sides toward the east and west, for setting up the Ptolemaic rulers [Regulae Ptolemaicae], as well as for supporting the smaller portable armillae when this is required. **K, L, N, O.** Globes resting on their supports, and sometimes set out in the said area, so that the sextants may be reclined against them for sighting toward any position of the stars. **M.** A round stone table, intended for setting up the portable quadrant and other smaller instruments on it, when desired, so that they may conveniently serve for observations. The rest, the observant and intelligent examiner will note for himself.

Explanation of the ground plan [ICHNOGRAPHIÆ EXPOSITIO]

A. The vestibule, by which one enters the observatory below by way of steps. **B.** The square hypocaust. **C.** The crypt for the great equatorial armillae. **D.** For the revolving quadrant. **E.** For the zodiacal armillae. **F.** For the great steel quadrant, having outside it a geometric square also of steel. **G.** For the four-cubit sextant set upon its revolving globe. **H, H.** Stone columns arranged on the western side. **I, I.** Other stone columns placed toward the east. **K, L, N, T.** Globes set outside for supporting the astronomical sextants. **M.** A round stone table. **O.** A couch, on

which I might sometimes rest while observing, if perhaps the clear weather did not allow continuous observation on account of the intervening clouds. **Q.** Another similar and larger one for the same use, for the students. **P.** A furnace. **V.** A table. **S.** The beginning of the subterranean passage, which I intended at some time to lead beneath the rampart and the garden into the castle, into the pyronomic [chemical/fire-working] laboratory. For it was begun, but not finished.

The outer area, with its gallery, has on each side of its square — facing the four quarters of the world — seventy feet. And the diameter of the semicircle intercepted in the middle place is twenty-four feet. In two of the corners of this square enclosure, toward Notapeliotes [SE] and Notolybicum [SW], are certain convenient recesses [Thecae]. In these is that larger semicircular instrument, by which the distances of the stars beyond a quadrant are taken — the depiction of which is not exhibited among the other instruments, but is only briefly indicated after them — as also the sextants and other similar movable instruments, whose use is not always required, which were kept under cover; just as I had also arranged to dispose certain other things, in due course, at the corners toward Borrhapeliotes [NE] and Borolybicum [NW].

Let these things be said briefly about these cryptic structures. If I wished to explain them all in detail, a lengthy description would be needed. The further verses which we assigned here and there in gilded letters in those same crypts, the same first book of the *Letters* exhibits, so that there is no need to repeat them here.

And let this much be said about the astronomical buildings as sufficient by way of indication. Although it was not my intention to set down here the island of the celebrated Danish Sound on which we built these things, nevertheless — because I made mention of the place where the buildings have been separately set up, and because this same island was already previously rendered in the fourth volume of the *Theatrum Urbium* [*Civitates Orbis Terrarum*] by the distinguished gentleman Mr. Georg Braun [Georg Braun], though not aptly enough through the carelessness of the painter — I have therefore thought it should be shown here a little more exactly.

Topography of the Island of Venusia, commonly called Hven

Diagram. Map (topographia) of the island of Venusia, commonly called Hven [Hven]. The island is drawn in plan within a ruled, graduated border (degree/minute scales along the margins). An ornate compass rose with many

rays occupies the upper-right (north) quarter. The cardinal directions are engraved as side-labels:

- (left margin, vertical): **MERIDIES.** (south)
- (right margin, vertical): **SEPTENTRIO.** (north)

The island's coastline, internal field boundaries, roads radiating from the center, woods, ponds, and the village are shown pictorially. Castle Uraniborg appears at the center (lettered **A**), with Stjerneborg adjacent (**B**), the village (**F**) below, the church (**H**), mills, ponds (**K, L, M**), and scattered cottages. The lettered features keyed in the legend below (A–T) are distributed across the island; many of the smaller marks are tiny and not individually resolvable, but the principal letters A, B, C, F, K, L, M, X are visible near the center.

Title (engraved, verbatim): **TOPOGRAPHIA INSVLÆ VENVSIÆ VVLGO HVENNA DICTÆ.** — "Topography of the island of Venusia, commonly called Hven."

Explanation of this topography [EXPLICATIO HVIVS TOPOGRAPHIÆ]

This island is set in the most celebrated Sound of the renowned Kingdom of Denmark, which divides Scania from Zealand. It looks toward the metropolis Copenhagen [Hafnia], in the direction of Libanotos [SSW], at a distance of three miles; toward Helsingør [Helsingora], where the royal Toll-house is, toward Circius [NNW], at a distance of two miles — these two being in Zealand; toward Helsingborg, which lies exactly to the north, also two miles distant; toward Landskrona [Landscrona], toward Eurus [E], one mile only; and toward Lund [Lundona], toward Eurus, likewise one mile — these two being situated in Scania.

The island is in itself quite high, as if one were climbing some mountain; yet above it is wholly flat, and has in its circuit 8,160 greater paces. About its center, where I built the castle Uraniborg, the elevation of the pole — or, what is the same, the latitude — is, from the equator, **G. 55. M. 54½** [55° 54½′], found by us most accurately and repeatedly. Its longitude, [reckoned] from the first parts [i.e. the prime meridian], is **36. M. 45.** [36° 45′], having regard, namely, to the difference of the meridians which Ptolemy and Copernicus used, and that of this place [established] with what diligence could be applied — just as in this square representation also, comprising the delineation of the island, these things are subdivided into single degrees and minutes [recte: along the borders]. The other things which are discerned in the island itself are to be understood thus:

A. The castle Uraniborg [Arx Uraniburgum]. **B.** Stjerneborg [Stellaeburgum]. **C.** The estate intended for the farm / household economy. **D.** The workshops of the

craftsmen who make the astronomical instruments and other things. **E.** A water-mill [literally "winged mill" — windmill]. **F.** A village [Pagus] containing about 40 dwellings of country-folk. **G.** A mill serving for making paper, and likewise grinding grain, and besides preparing various hides — which three works one and the same very great wheel accomplishes at once as well as it would separately. **H.** The church [Templum]. **I.** The country-folk's court of justice [Forum iudiciale Rusticorum]. **K, L, M.** The larger fish-ponds, of which **L, M** are assigned to the mill, of great depth, and founded with a dam of incredible mass, so that there may be a reservoir of water for the use of the mills. **[H]** The remaining fish-ponds, about 60 in number, containing a great abundance of fish of various kinds for the use of the said mill, easily emptied for the most part when there is need. **O.** A marshy meadow, with some alders rising up. **T.** Pastures planted in some places with trees. **N.** A little wood of hazels, shaded, on the northern shore. **P, Q, R, S.** The traces of four [former] castles, which once stood there.

When King Frederick II [Frederick II], of most laudable memory, had granted me this island for life — and had confirmed it by letters given on parchment, so that I might here pursue astronomical matters with competent leisure (as I also noted before) — I expended enormous labors and expense upon it, in order to serve the will of that excellent king and the honor of the fatherland, not only by the splendid and solid buildings constructed on it, as has been indicated, but also by very many waterworks (where there had previously been nothing of the kind), heaped up here and there, so that I might set up there at the shore of the sea a paper-mill suitable for making paper, which would supply my printing-house, likewise cultivated there, with paper that would otherwise have had to be sought from Germany, not without difficulty.

Moreover, I LAID OUT [INSVMPSI] upon all these things beyond ton[s] of gold — whatever, namely, I was able to acquire, whether from the king's benefactions or from my own annual revenues, I spent upon these uses. About the troubles and the enormous labors which I endured there for 21 years, I shall add nothing. From these and other matters, any sound-minded person will easily estimate that it was for no light reasons — especially at this age of fifty, and with a great household — that I left an island of such constant [worth], and at the same time my sweetest fatherland, together with my kindred by blood and very many friends. But what, and how great, the things were that drove me to this, I here willingly pass over in silence.

Meanwhile, my most serene King Christian IV [Christian IV], my most clement lord — who lately succeeded the father, King Frederick of most laudable memory, the founder and promoter of these things here — I gladly hold excused. For I do not doubt that, if matters concerning this business (perhaps not without honor for the Kingdom) had been laid before him in good time and sufficiently, then — given his heroic nature and quick wit, his generous spirit, and his excellent endowment of an intellect inclined to the arts — he would have clemently and liberally preserved and perpetuated, in his own Kingdom, these studies most worthy of kings. But perhaps it was so ordained that the restoration of astronomy might be more widely promulgated and rendered more universal. Indeed, from this anyone will easily and confidently weigh how seriously and zealously the restoration of astronomy is at my heart — since I was willing to bear bravely all the labors and expenses, all the disturbances and adversities arising from it, to the point that I did not even hesitate to leave behind my dearest fatherland.

SO GREAT A LOVE OF THE STARS DROVE US TO TRACE OUT THEIR LAW. [TANTVS AMOR NOBIS ASTRORVM EXPANGERE NORMAS.]

Supplement on the subdivision and the sights of the instruments [SVPPLEMENTVM DE SVBDIVISIONE ET DIOPTRIS INSTRVMENTORVM]

Since in the foregoing, when I was treating of the instruments, I did not express in figures the transversal subdivision and the sights [dioptrae] — because they were not so quickly at hand — I am pleased to append them here, so that this matter may be more correctly understood.

The method of the division having transversal points is thus, as this figure expresses: in it, each set of ten minutes is marked off distinctly by little lines into ten equal intervals by points; and so the rule of the line of sight [regula fiduciae], passing between any of these during observation, yields the very minute of the degree that was sought, or some part of it, according as it is discerned to be removed from this or that point. I learned this in my youth at Leipzig [Lipsia], adapted indeed to rectilinear parallelograms, to which it also properly belongs; yet I afterwards applied it suitably enough to the arcs in my instruments, just as a decade ago, in our book *On the Comet of the Year 1577* [*De Cometa Anni 1577*], near the end of page 461, I suggested in these words:

> *For although its demonstration properly suits rectilinear parallelograms, nevertheless it is also fittingly applied to arcual lines in so small an interval*

— one that differs from a straight line imperceptibly — without any trace of error.

But that I may add a demonstration of this also here, on account of certain smatterers perhaps who carp at things they do not sufficiently grasp, take it thus.

Diagram. A geometric construction (a narrow triangular/sector figure) accompanying the demonstration. Visible point-letters: **A** (apex/center of the instrument, at the bottom), **O** (upper right), and along the figure **N, F, E, V, Y, I, B, H** — the radius A,O and the transversal subdivision near O,I are drawn. The lettering matches the computation below: A = center of the instrument, A,O = semidiameter, O,I = the strip in which the transversal division falls.

In the assigned figure, let **A** be the center of the instrument, and **A,O** its semidiameter. Let **O,I** be taken as the small part in which this division by transverse lines is made, in the proportion which is 1 to 48 — such as is most often employed in my instruments. And since A,I is set as **1000000000** parts of the whole greater Canon of Rheticus [Canon of Rheticus], A,O of the same will be **20833333⅓** — being the forty-eighth part of the radius. Arc f,E is **50′** and I,V **10′**; the sine of these is **2908779**. Y,I, the second sine of the same [the versed sine], is **42308**. V,Y, which added to N,V (this being equal to O,f) makes N,Y, is **20875641**. In the triangle, therefore, N,Y,I, right-angled at Y, two sides are known, N,Y and Y,I; whence the base I,N, **20396208**, is given, together with the angle N,I,Y, **82°. 3′. 10″. 47‴**. To this is added Y,I,A, **89°. 50′.**, which makes N,I,A, **171°. 53′. 10″. 47‴**. And the base N,I, in the right triangle N,Y,I, is divided into ten equal parts, so that they may correspond to a single minute, **2103962⅗**, represented by I,B.

Next, in the oblique-angled triangle B,f,A two sides are given, I,E [recte: I,B] and I,A, the radius, together with the angle B,I,A, which is the same as the angle N,I,A, **171°. 53′. 10″. 47‴** found just before. Whence the angle I,A,B becomes known, **3′. 1″. 7‴**, which ought to be only **3′**; so that it is greater by at most **1″. 7‴** — a truly imperceptible difference. Likewise, if f,I be taken as nine little parts, [the sine] will be **1893565⅞** [?], and we shall again have the triangle F,I,A, in which two sides are given, F,I just stated, together with the radius f,A and the angle F,I,A comprehended by those same, as before; and the angle I,A,F arises, **9′. 1″. 6‴**, which ought to be **9′** exactly, falling short in the last minute by **1″. 6‴**.

Further, that the same may be tried about the middle which we have now done at the extremities, let there be found, by the same reckoning as before: first, the angle f,A,H, **5′. 3″. 6‴**, exceeding [the true value] by **3″. 6‴**; second, the angle N,A,H, **4′. 56″. 55‴** [?], falling short by **3″. 5‴**. It is therefore plain that the greatest

difference — whether additive or subtractive — that arises in this practice is at the most something a little beyond **3″**; which the keenness of vision's acuteness can by no means sustain in any instrument whatsoever (a thing which is in itself idle). Wherefore those who presume to cavil at this our sufficiently accurate form of distribution are seeking a knot in a bulrush [i.e. a difficulty where none exists]. Moreover, in certain instruments, especially the larger ones, where the radius is longer, we are accustomed to carry out this subdivision by five minutes only; and so that little difference of which we speak becomes still more imperceptible — which is what we proposed to demonstrate.

Of the little sighting-vanes, or sights [pinnacidia / dioptrae], we have devised this arrangement, most apt for use: that the slits in the lower sight, nearest the eye, be made four, around all its sides — which are precisely analogous to the upper one, and equally distant from and correspondent to its four sides with respect to the line of sight [linea fiduciae] — as you see represented in the appended figure, so far as could be done in a plane.

Diagram. A schematic of the paired sights (pinnacidia) mounted on a ruler. Visible point-letters: the nearer sight (next to the observer's eye) is lettered **A, B, C, D**; the farther sight (toward the instrument's circumference) is lettered **E, F, G, H**; **I** marks the ruler [regula] to which the two sights are fixed at right angles. The slits and the adjustable pinnules are shown around the frame.

There, **A, B, C, D** designates that nearer sight, brought close to the observer's eye; and the other, **E, F, G, H**, the one that is far off, at the circumference of the instrument. **I** marks the ruler, to which these sights are fittingly fixed at right angles. The sight F,G,H,E must be wholly equal to the other, B,C,D,A. On the lower sight, however, little pinnules are applied on three sides, on that part where they are nearest to it, [made] rectilinear, [and] can be compressed against or relaxed from the sight itself by means of certain clasps — so that they make the slits at this [sight] everywhere equal, which it will also be permitted to widen or narrow according as use demands. And this can be accomplished by a certain particular device, on the other and inner part of the sight, by a single screw turned around, so that all the slits are at once equally and uniformly, by one motion, relaxed or tightened without labor or loss of time.

The fourth slit, which is in that part of the sight where it adheres to the ruler, remains forever cut [fixed]; it is represented a little above B, A, to which — equidistant from the plane of the ruler — another slit is seen in the upper sight, near F, D. Although that inner one, no less than the other three aforesaid, can also

be suitably diminished and increased by a little added attachment, according as need requires.

The USE is in taking the altitudes of the stars: that the ruler I be raised or lowered until the star is seen through the slit D, A on the side of the other sight, A, E; and at the same instant just as much be seen from below through the slit B, C, alongside the other side G, F. For then there is no doubt that the sighting [collimation] of the star itself has been made central and exact. But if you wish to obtain the azimuth as well, attention must be paid through another slit, alongside C, D, to the front side G, H; and one [slit] through the slit G, H, near the other...

the other [sight]; and so an observation is most readily set up upon a star. But on the Sun, through the round aperture of the upper sight, the rays admitted from the inner part fill on every side a certain little circle marked there on the lower [sight] — proportioned to the quantity of light that the Sun casts through that opening — and so yield what is sought. It should further be noted that in certain of the instruments the sight that is set farther from the eye is of cylindrical form; and the matter comes to the same thing, except that in the case of the Sun the shadow of the cylinder must be attended to. So too on the armillae we fit a certain rounded axle, so that sighting can be done all around it; for both cylinders and rounded axles have this advantage especially, that they serve not just one but even two observers at once. The rest the figure itself — or rather the practical use of such instruments — will teach more fully.

This method of observation through equidistant slits in the other sight, necessity itself taught me. For through round apertures, in the manner otherwise customary, stars are seen with the greatest difficulty — particularly the one that is set farthest from the eye — unless that aperture is wide enough; and if this is granted, some fractional part of a degree can be lost, since one does not know whether the sighting is exactly central. I am genuinely astonished that this was not noticed by earlier astronomers, and that no other provision was made against this drawback. When a certain distinguished mathematician, some years ago, had come from a far journey to visit me for the sake of inspecting my instruments, and had examined this way of marking down the stars so conveniently by means of slits arranged in this fashion, he leapt up for joy, declaring that he had now received the very thing he had panted after in vain for many years before, and he congratulated himself that on this account alone his coming to Denmark had not been wasted. Afterward, on coming to Kassel, he applied it as best he could to the Landgrave's instruments — and likewise the manner of the subdivision by transversal points — as is clear in its place in the first volume of the *Astronomical*

Letters, from the correspondence exchanged between Wilhelm, Landgrave [of Hesse] of most praiseworthy memory, and his mathematician and myself. And let it suffice to have thus indicated this much, both concerning the sights and concerning the form of the subdivision.

To the truly Illustrious and Noble man TYCHO BRAHE, Lord of Knudstrup, Prince of Astronomers.

An Ode, Tricolos Tetrastrophos.

Latin (as printed, recovered at native resolution):

Romanus olim dum tumidos Getas Infestat armis, aut mare ponticum, Gangeq; miles, inque Mædos Fert aquilas & acuta pila: Nullo potentem stare diu loco Strinxere divam compede, ne feros Visens Gelonos, aut sagittâ Conspicuos inimica Parthos: Ludo insolenti ferret in arduum, Versis ad imam Rimulidis rotam. Sic ferreo alligata vinclo & Præpetibus viduata pennis Victoria, olim Cecropios lares Coacta fovit. Quis Tyrio Iovem Sterisse [recte: Stetisse] nescit alligatum Compete, purpureas ad aras? Lixior venenum tabificum intimis Serpens medullis, cuncta sibi serens Nil alteri; cæleste numen Posse coli populos per omnes Invidit. At non Dania Balthici Superba frænatrix pelagi cluens: Non illa (quamvis justiori Te poterat tenuisse vinclo O TYCHO) tandem Teuthonicis dari Invidit oris. Tu patriæ tuæ Nomen perennando, per omnes Conspicuum volitare gentes Sollers dedisti: Quisquis enim tuo Ductu eruditus per vaga sidera Cælique inextricata quondam Regna, oculos animumq; voluit: Et justiori tramite certior Designet, ecquid terrifici ferant Mundo Cometæ: quis polorum Sit positus, varietq; fata: Sive ille latam Theuthoniæ incolat, Vel Galliæ eram [?], seu veteres Quados Bohemiamq; & Marcomannos Hesperiæve utriusq; regna: Votiva gratus carmina se tibi

Quem Lusitanis ire triremibus Ad Calecuti ditis aromatum Portus, in eosq; Chinæ Quinzaidem Iaponesq; eogit [recte: egit]. Hic ipse ductu dum melius tuo Scrutatur astra & per mare certior Decurrit, ignoto vetustis Tramite, dum meritas laboris Grato elocutus murmure gratias Tibi rependit, Tum Daniam quoque Honorate altricem, imo matrem: Te loquitur FRIDerice, Regum Longo micantem syrmate: Te canit Fovisse regno (non genitum Iove Tyrinthium, cervice cujus Firmior axis uterque mundi Pependit olim, cum Iapeto satus Defessa solvit colla vicario) Ast hûc qui inobservata signa, & Perpetuos sine lege certâ

Frenavit orbes. Qui super igneas Devectus arces dotibus ingeni,
Conspexit in quo fixus orbe Conficeret sua singna [recte: signa] Phæbus, Phæbeque. Vt illis machina terrea Vtriusque centrum præbeat, ut Venus Cyllenium secuta sidus, Ambiat ignivomas quadrigas Majore gyro. Martis ut orbitam Iovisq; currum & tardigradi sonis [recte: Senis], Cen [recte: Ceu] cordis instar atque centri, Æthereâ moderetur arte Cælestium Sol arbiter orbium Mundiq; rex. Vt jam neq; dogmate Copernicea, nec tui nos Detineant Ptolomæ [recte: Ptolemaei] cycli. Sunt fore qui Danmarchica Martiis Ornent tropheis regna, & adoreis, Sunt forte qui regem decorent Consilioq; manuq; promti: At TYCHO diæ mentis acumine Pridem exulantes Vraniæ choros,
Atque astra devocata cælo, Arte tuis FRIDERICE regnis Inclusit audax: Nominis hic tui Sceptriq; famam supra hominum genus
Mortale, deduxit per omnes Limitis ætherei meatus. Qui posse credat? TYCHO tuis dedit Terrestre cælum (sit mihi fas novâ
Miraculum explicare voce) Ille animum inperiumq; Olympo Æquavit. Et quæ plura fetebitur [recte: fatebitur] Gratus labori quisquis erit, sacris Non invidenti felle tinctus Vraniæ operatus aris.

Nec nostra te Germania lividas Obliviones carpere perferet Ingrata: Nam tui videndi Dum nimium studiosa, septem Abisse questa est diu trieterides, Post vota tandem te sibi redditum Blande salutans, absit, inquit, Non sine Dijs mihi missus hospes, Sat te rigentis frigora Balthicæ Tulisse mundo condolet exulem: Sat algido datum Trioni, Et Boreæ male pertinaci Fovere sacros Vraniæ lares Adsis secundo numine, & hoc tui Vultus jubar serenioris Exere Teuthonicas qer [recte: per] urbes. Laboriosum non ita Vlyssea Lætata vidit penelope, aut puer, Qui primis agnovit parentem Telemachus, trepidæq; matres; Vt nostra te Germania in hoc suum Venisse regum gaudet, ubi tuæ Illustre virtuti theatrum, & Debitus ingenio patronus. Cum te RVDOLPHI Cæsaris audiet Permista Majestate benignitas, E patriâ haut considerante
Tanta sui monumenta honoris, Cessisse, tecumq; Vraniæ chorum: Nitetur ultro hanc laureolem suis Iunixisse [recte: Iunxisse] Sceptris, & triumphis, Teq; tuasq; fovebit artes Vultu benigno. Scimus ut Austriæ Prognata cælo progenies simul Musasq; ferratumq; Martem
Temporibus generosa utris q [recte: utrisque]: Conjungat: ut mox Threicii ducis Fastum insolentem milite contudit Lenire dum quærit labores, Vraniæ recreetur hortis. Mecum Viennæ culta Academia Laudabit Albertos geminos; patrem Natumque, qui sacro calentem
Igne animum super alta vexit Devotus astra: ûde [recte: unde]

ASTRONOMI tulit Cognomen. Ernesti sileam genus Te Friderice, longâ gentis Gloria, Teuchoniciq; Sceptri? Sub hoc patrono Regiomontius [recte: Regiomontanus] Fulsit Iohannes Vraniæ decus: Quem Parca, fatalisq; livor Morte nimis properata ademtum Terris removit Ille triangulos, Ille expolitam Mechanicen dedit: Quin Noriberga fabricantem Obstupuit, stupuitq; Cæsar, Agreste lignum dum medio aspicit Volare cælo. Credite posteri, Fugisse cum nato parentem Gnossiacis per inane claustris.

Quid Dædaleæ non facient manus? Mensq; illa sacro cocta scientiæ Phæbo, cui divinioris Particulam genij Promethei [?] Cælestis indit? O nimium, TYCHO, Beata tellus, quæ ingenij tui Miracula, atque artes videbit Pyronomas, Medicamq; dextrâ Morbos in arces. Tu Vraniæ quidem Princeps catervæ; nec minus omnium Scientiarumq; artiumq; Nobilium studio expolitus. O ille felix, cui dabitur tuo Ab ore terreni harmoniam globi Conferre cælo! ut hic & illic Sidera, sintq; sui Planetæ, Vtriq; mundo. Tu Chymici à potens [recte: ô potens] Arte & metallis, lanificas deas Producere incidata vitæ [recte: incidatæ vitæ] Stamina, tu vacuam Charontis Tranare cymbam sæpe jubes. Tibi. Narragiæ [recte: Norvagiae] quos frigora, & horridi Premunt Triones, atque regna Danica cum Suenos rependent [recte: Suenones] Grates merenti (Si qua tamen bonus Forsan rependent sæcula gratiam, Livorq; permittat tuo te Pro meritis cumulari honore. Te Sontici [?] Tartareæ simul Gement podagræ mancipia, undiq; Te tabe consumti querentur E patrijs abijsse regnis Fletu madentes. Nos tamen hinc tibi Congratulantes concinimus melos Votivum, & optata intuemur Ora, manusque diu cupitas. Exosculamur. Vos diadematis Septem columæ [recte: columnae] Cæsarei, ô duces Regesque, quos cælestis ardor Igne coquit generosiore: Scientiarum vos ego nomine Compello, mecumque Vraniæ chorus? Et tota Hiantidum corona Auspicio reparanda vestro, Opem requirit. Ne sinite hoc decus, Germaniæ præ finibus, Italas Vrbes, vel extremos Britannos Abripere, occiduosve Francos: Rivalis illinc Gallia, vos procul Limis tuetur, vos Itali volent Laudis fuisse negligentes, Vos oculo virgil [recte: vigil] irretorto Ferax virorum Hollandiâ, & ultimi Notant Britanni: Vos borealior Scotusq; & audaces Iberi Oceano tumidi reperto. Quid quique anhelent dispiciant; ego Germaniam istâ laudis adoreâ Confido fulgentem videre Vraniæ hospitio supra omnes.

English rendering:

The Roman, long ago, while he harried the swelling Getae [Getas] with arms, or [troubled] the Pontic sea — the soldier of the Ganges, bearing his eagles and sharp javelins against the Medes [Maedos] — bound the goddess fast with fetters, lest, powerful, she stand long in any one place: lest, visiting the fierce Geloni [Gelonos], or the Parthians [Parthos] conspicuous with the unfriendly arrow, by insolent sport she be carried aloft, the wheel of fickle fortune turned to its lowest. And so Victory, bound with iron chain and stripped of her swift wings, once was forced to cherish the Cecropian household-gods [the Lares of Athens]. Who does not know that Jove himself stood fettered with Tyrian fetter at the purple altars?

A wasting poison, creeping like a serpent in the inmost marrow, sowing all things for itself, nothing for another — she begrudged that the celestial power could be worshipped by all peoples. But Denmark did not — Denmark, proud and renowned as the bridler of the Baltic sea: she did not (although by a juster bond she could have held you back, O TYCHO) at last begrudge that you be given to the German shores. To your fatherland you, ever-renewing its name, skillfully granted that it flit conspicuous among all peoples. For whoever, instructed by your guidance, has turned his eyes and mind over the wandering stars and the once-inextricable realms of the heaven —

and by a juster path more surely marks out what terrors the comets [Cometae] bring upon the world, what the position of the poles may be, and how they vary the fates —

whether he dwell in broad Germany [Theutonia], or in the land of Gaul [Galliae], or among the ancient Quadi [Quados], Bohemia [Bohemiam] and the Marcomanni [Marcomannos], or the realms of either Hesperia [Hesperiae] — he, grateful, [pledges] his votive songs to you;

he whom it drives to go in Lusitanian [Lusitanis] triremes to the harbors of Calicut [Calecuti], rich in spices, and into those of China [Chinae] — to Quinsay [Quinzai] and the Japanese [Iapones]. This man himself, while by your better guidance he scrutinizes the stars and runs more surely over the sea, by a path unknown to the ancients — while, eloquent with grateful murmur, he repays to you the merited thanks of his labor — then honors Denmark [Daniam] too as his nurse, nay his mother:

he speaks of you, FREDERICK [Frederice], gleaming among kings in a long train; he sings that you fostered in your realm (not that Tirynthian [Hercules] born of Jove, on whose neck either firmer axis of the world once leaned, when the son of Iapetus [Atlas], wearied, freed his neck by a substitute) — but rather him who

reined in the unobserved signs and the orbs forever running without sure law. He who, borne above the fiery citadels by gifts of genius, beheld in what fixed sphere Phoebus [the Sun] and Phoebe [the Moon] complete their courses;

so that for them the earthly machine [machina terrea] may furnish a center to each — so that Venus [Venus], following the Cyllenian star [Mercury], may circle the fire-spewing chariots [of the Sun] in a greater gyre; so that the Sun, arbiter and king of the heavenly orbs of the universe, may by ethereal art govern, like the very heart and center, the orbit of Mars [Martis], the chariot of Jupiter [Jovis], and that of the slow-paced Old Man [Saturn].

So that now neither the Copernican [Copernicea] doctrine nor the Ptolemaic [Ptolemaei] cycles may detain us.

There may be those who would adorn the Danish [Danmarchica] realms with the trophies and glories of Mars [Martiis]; there are perhaps those who would grace the king, prompt in counsel and in hand: but you, TYCHO, by the keen edge of your divine mind, boldly enclosed the long-exiled choruses of Urania [Uraniae], and the stars summoned back from heaven, by your art, FREDERICK, in your realms. The fame of your name and scepter, beyond the mortal race of men, he carried through all the passages of the ethereal track.

Who could believe it possible? TYCHO has given to your people an earthly heaven (if it be lawful for me to unfold the miracle with a new voice); he has matched mind and empire to Olympus [Olympo]. And whatever more anyone, grateful for the labor, shall confess — whoever he be, tinged with no envious gall — he will have done sacred service at the altars of Urania.

Nor will our Germany [Germania], ungrateful, suffer dark Oblivion to carry you off: for, too eager to see you, she complained that seven three-year periods [trieterides] had long passed [without you]. After her prayers, at last greeting you fondly, restored to herself, she said: "Far be it — not without the gods has my guest been sent to me; she grieves enough that you, an exile, bore for the world the frosts of the rigid Baltic [Balthica], enough that you were given to the chilly North [Trion] and to the ill-stubborn North wind [Boreae]. Cherish the sacred household-gods of Urania; be present with favoring power, and shine out this radiance of your serener countenance through the German [Teuthonicas] cities."

Not so did toil-worn Penelope [Penelope] gladly behold Ulysses [Ulysses], nor the boy Telemachus [Telemachus], who first recognized his parent, nor the trembling mothers, as our Germany rejoices that you have come into this her realm of

kings, where there is an illustrious theater for your virtue, and a patron owed to your genius.

When the kindness of RUDOLPH [Rudolph] the Caesar, mingled with his Majesty, shall hear that — your fatherland scarcely considering — such great monuments of his own honor have departed, and the chorus of Urania with you, he will of his own accord strive to join this little laurel to his scepters and triumphs, and will foster you and your arts with a kindly countenance. We know how the progeny of Austria [Austriae], born from heaven, joins at once the Muses [Musas] and iron-clad Mars [Martem], generous in either age: so that presently, as it crushed by soldiery the insolent pride of the Thracian [Threicii] leader, it may, while it seeks to soothe its labors, be refreshed in the gardens of Urania.

With me the cultivated Academy of Vienna [Viennae] will praise the twin Alberts [Albertos geminos], the father and the son, who, devoted, raised on high to the stars above the mind warm with sacred fire: whence he took the surname of ASTRONOMER. Should I be silent of the line of Ernest [Ernesti] — of you, Frederick, long glory of your house and of the German [Teuthonici] scepter? Under this patron Johannes [Regiomontanus] shone, the glory of Urania [Uraniae]: whom the Fates [Parca] and deadly envy snatched away, taken by a too-early death, and removed from the earth. He gave the world triangles [trigonometry], he gave polished Mechanics: nay, Nuremberg [Noriberga] marvelled at him fashioning [it], and Caesar marvelled, when he beheld rustic wood fly in mid-heaven. Believe it, posterity: the father with his son fled through the void on Cretan [Gnossian / Daedalian] wings [claustris] —

what will the Daedalian [Daedaleae] hands not accomplish? — and that mind, cooked for Phoebus by sacred knowledge, into which heaven instilled a particle of the diviner genius of Prometheus [Promethei]. O too-blessed earth, TYCHO, which shall see the miracles of your genius, and your arts: a master of fire [Pyronomus] and a physician [Medicus], driving diseases by your right hand into their strongholds. You indeed are Prince of Urania's [Uraniae] band, and no less polished by the study of all the noble sciences and arts.

O happy he, to whom it shall be granted to confer from your mouth the harmony of the earthly globe upon the heaven — so that here and there the stars and their own planets [may belong] to either world! You, mighty by the art of the Chemist [Chymici] and in metals, often bid the wool-spinning goddesses [the Fates] produce the threads of a life cut short, and bid [the dead] sail back across the empty skiff of Charon [Charontis]. To you those whom the frosts and the dread North [Triones] press, and the Danish realms together with the Swedes

[Suenones], will repay the thanks you merit — if any kindly age shall perhaps repay the grace, and envy permit you to be heaped with honor for your merits.

For you the chained slaves of Tartarean gout [podagrae] will groan on every side; consumed by wasting disease, they will complain that you have departed from your native realms, their faces streaming with weeping. Yet we from here, congratulating you, sing a votive song, and behold the longed-for face, and kiss the hands long desired. You, seven columns of the Caesarian diadem [diadematis], O leaders and kings, whom the heavenly ardor kindles with a more generous fire: you I summon in the name of the Sciences, and with me the chorus of Urania; and the whole crown of the Muses [Hyantides], to be restored under your auspices, requires aid. Do not allow this glory to be snatched, from before Germany's borders, by the Italian [Italas] cities, or the farthest Britons [Britannos], or the western Franks [Francos]: the rival Gaul [Gallia] watches you askance from afar; the Italians will wish you to have been negligent of your praise; with unaverted, watchful eye [vigil] the man-bearing Holland [Hollandia] marks you, and the farthest Britons, and the more northern Scot [Scotus], and the bold Iberians [Iberi], swollen with pride over the Ocean now discovered. Let them despise whatever each may pant after; I trust to see Germany, shining with this glory and adornment, above all others in the hospitality of Urania.

RUDOLPH CAUKERCHIUS [Rudolph Caukerchius], of 's-Hertogenbosch [Sylvidux Belga — Silva Ducis], a Netherlander, on account of his devoted reverence and love. He composed it ["F." = fecit].

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[Binding]

Spine of the binding.

This final image is a photograph of the **spine** of the vellum binding, shot edge-on against a black background. The volume is bound in limp vellum (parchment) over the gathering structure; the raised horizontal creases mark the sewing supports / gathering bands across the spine.

No printed text is present — this is binding material, not a text leaf. The vellum shows the usual age-staining, soiling, and surface abrasion of an early-modern parchment spine.

Two manuscript/ink traces are faintly visible on the spine, but neither can be resolved:

- A vertical run of faded manuscript ink along the lower-middle of the spine — possibly an old shelf title or hand-lettered label, now largely effaced. [Illegible: faded manuscript on vellum spine]
- A small ink mark or modern shelf-number near the foot of the spine, in a bluish ink. [Illegible: shelf mark at spine foot]

No legible shelfmark, motto, printed lettering, or gilt tooling is discernible.