Visual and Verbal Commentaries in Renaissance Astronomy: Erasmus Reinhold's Treatment of Classical Sources on Astronomy

Pietro Daniel Omodeo

Ca' Foscari University of Venice

ERC Endeavor *EarlyModernCosmology* (GA 725883)

Irina Tupikova

Lohrmann Observatory, TU Dresden

1. Introduction

The commented edition of Ptolemy's *Almagest*, book one, *Ptolemaei Mathematicae constructionis liber primus* (Wittenberg, 1549) authored by the Wittenberg professor of mathematics Erasmus Reinhold (1511-1553), is a wonderful example of a Renaissance commentary of a mathematical-astronomical text from Hellenistic antiquity. In this essay, we consider this source and other commentaries stemming from the same environment in order to address a series of questions that we deem to be relevant for a correct understanding of commentary practices in general. Above all—and in line with the exploratory work by Glenn Most[1]—we intend to stress that the form of the commentary depends on the contents it deals with and the disciplinary field it belongs to. Unlike commentaries on philosophical and

[1] See Glenn Most (ed.), *Commentaries / Kommentare* (Göttingen: Vandenhoeck und Ruprecht, 1999).

religious sources (e.g., commentaries of the Aristotelian corpus and biblical exegesis), in the case of mathematical astronomy the visual dimension (e.g., the models used in planetary theory and cosmological diagrams) plays an essential role. We specifically refer to geometrical visualization as a necessary tool for the interpretation and explanation of sources on spherical astronomy and planetary theory. By "visualization" we do not mean the trivial fact that all writing and spatial organization of a text implies a visual element (e.g., the mirror-like quality of glosses, adjacency of marginal commentary, the proliferating medieval classificatory stemmas and the like). Rather, we deal with the use of technical diagrams apt to represent, explain and investigate mathematical astronomy. This kind of representation is neither visual in the loose meaning of the term nor pictorial but strictly geometrical. Moreover, the interpretation of mathematical (and astronomical-mathematical) sources requires an analysis of diagrams or their creation, if for some reason they have not been transmitted to the recipient, today just as in the Renaissance. Therefore, we feel compelled to reinterpret the Renaissance visual commentaries with the support of new ones helping us to assess both the original sources and their later commentaries. We not only discuss Renaissance diagrams; we also interpret them using graphic means to ease the modern reader's comprehension of past representations. Although this approach might appear anachronistic at first glance, we deem it expedient—even necessary. One should not forget that actualization and reinterpretation are the salt of all commentaries, past and present.

Moreover, we should consider the cultural environment of the visual commentaries in order to comprehend which questions a commentator asked of his sources. In our case, we deal with writings arising out of the university reforms of Philipp Melanchthon (1497-1560) and the early reception of Copernicus (1573-1543). The increased relevance of mathematical astronomy among the curricular disciplines at the Lutheran-Melanchthonian university of Wittenberg during the sixteenth century determined Reinhold's interest in cosmological questions, their embedment in theology and their connection with pedagogy.

In those years, the appearance of Nicolaus Copernicus's *De revolutionibus orbium coelestium* (Nuremberg, 1543), propounding a heliocentric planetary theory, cast traditional geocentric and geostatic arguments into doubt. The publication of what is considered to be the most important astronomical work of the Renaissance was made possible thanks to the mediation of the former Wittenberg professor of mathematics and Reinhold's ex-colleague Georg Joachim Rheticus (1514-1574). In 1539, Rheticus traveled from Wittenberg to Frombork in Varmia to meet Copernicus in person and learn about his novel hypotheses. Under the supervision of the Polish astronomer, Rheticus had prepared a report of the former's most daring views, *Narratio prima* (Gdańsk, 1540). Later, he brought the manuscript of *De revolutionibus* to Nuremberg, where Johannes Petreius (ca. 1496-1550) printed it in his printing house. Copernicus' work impacted Wittenberg's astronomical debates.

At Wittenberg, the physical and scriptural difficulties entailed by the new approach to planetary theory were addressed immediately. The leading intellectuals at Wittenberg deemed the natural and scriptural hindrances to be so severe as to make the motion of the Earth and the centrality and immobility of the Sun unacceptable, although they agreed on salvaging the mathematics and the parameters of *De revolutionibus*. Most importantly, Reinhold's mentor Melanchthon pointed out the insurmountable scriptural and physical problem in his introduction to physics, *Initia doctrinae physicae* (Introduction to the Physical Doctrine) (Wittenberg, 1549). Reinhold collaborated with Melanchthon on the revision of this work.[2] Melanchthon refused to abandon geocentric physics and the established exegesis of those scriptural passages referring to a moving Sun and a central and immovable Earth. Reinhold, who was one of the first readers of Copernicus, appreciated the mathematical expediency of the latter as well as his improved astronomical parameters. Reinhold also compiled the first astronomical tables based on the values of *De revolutionibus*; they were entitled *Prutenicae tabulae* (Prussian Tables) (1551) and widely circulated even beyond the network of Protestant scholarly institutions.

Yet, in order to accept the Copernican theory, *De revolutionibus* had to be read in conventional terms, as a mathematical exercise without physical meaning. Copernicus's geometrical models had to be reworked and transposed into a more familiar geocentric fashion. While the somehow conventionalist perspective was promoted by the theologian Andreas Osiander (1498-1552) in the anonymous letter that he attached to the beginning of the Nuremberg edition of *De revolutionibus*, the geocentric transposition of Copernicus's geometries became a sort of research

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[2] Walter Thüringer, "Paul Eber (1511-1569): Melanchthons Physik und seine Stellung zu Copernicus," in *Melanchthon in seinen Schülern*, ed. Heinz Scheible (Wiesbaden: Harrassowitz, 1997).

program for Wittenberg scholars. It culminated in the Eighties in the development of hybrid systems, known as *geo-heliocentric* because they kept the cosmological centrality of the Earth but assumed that all other planets encircle the moving Sun.[3] The mathematical reception of Copernicus (focused on geometrical modeling and improved parameters and dismissive of the heliocentric-and-geokinetic hypothesis) is known among historians of Renaissance astronomy as the "Wittenberg interpretation". After Robert Westman first emphasized its historical relevance,[4] scholars have discussed the epistemology and physics underlying this line of reception. Among others, Peter Barker and Bernard Goldstein convincingly argued that early readers of Copernicus in Protestant Germany were not conventionalists in the modern sense of the term and were by no means uninterested in dispelling the natural philosophical dimension of astronomy.[5] Simply, Melanchthon and his pupils did not abandon the tenets of Aristotelian physics and this led to a transformative reception of Copernicus aimed at the reconciliation of new astronomy and old physics (and biblical exegesis). At the same time, they felt compelled to reconsider the geocentric arguments carefully, as is evidenced by their writings and most pointedly by the textbooks they produced. Melancthon's introduction to physics, *Initia doctrinae physicae*, is a clear instance of the enduring legacy of Aristotelian natural philosophy. The sources we discuss, Reinhold's commentary on Ptolemy's *Almagest* book one and on Pliny's *Historia naturalis*, are further instances of the efforts that were made to reassess classics of astronomy and cosmology in the light of Melanchthonian pedagogy and post-Copernican astronomy.

2. Reinhold's place in the history of science

[3] Nicholas Jardine and Alain Segonds, *La guerre des astronomes: La querelle au sujet de l'origine du système géo-héliocentrique à la fin du XVIe siècle* (Paris: Les Belles Lettres, 2008). The epistemological problems linked to the status of mathematical modeling and physical explanation is discussed at length in *Copernicus in the Cultural Debates of the Renaissance: Reception, Legacy, Transformation in the series Medieval and Early Modern Science* (Leiden: Brill, 2014), Chap. 2, "Astronomy at the Crossroads of Mathematics, Natural Philosophy and Epistemology."

[4] Robert S.Westman, "The Melanchthon Circle, Rheticus and the Wittenberg Interpretation of the Copernican Theory," *Isis* 66 (1975): 163-193.

[5] Peter Barker and Bernard R. Goldstein, "Realism and Instrumentalism in Sixteenth Century Astronomy: A Reappraisal," *Perspectives on Science* 6/3 (1998): 232-258.

Erasmus Reinhold of Saalfeld can be regarded as the most prominent northern European astronomer between Copernicus and Tycho Brahe. He was appointed as a professor of mathematics at Wittenberg in 1536, in the years in which Melanchthon forged a generation of Lutheran humanists there. Melanchthon fostered the study and teaching of mathematics and astronomy, especially in connection with astrology, which he considered to be the science of God's providence acting through nature.[6] Reinhold owes certain renown to his collaboration with Melanchthon, to whose circle he belonged—and excellent studies have demonstrated the relevance of his work for the history of mathematics at Lutheran universities and beyond.[7] His most important achievement was the computation of "Copernican" tables, the *Prutenicae tabulae* printed in Tübingen in 1551.[8] As a colleague of Copernicus's only pupil Rheticus, Reinhold was one of the first to read *De revolutionibus* and made good use of this opportunity. Most sixteenth-century calculators of new tables and countless compilers of ephemerides relied on his astronomical tables, which were seen as a valuable alternative to the earlier *Alfonsine Tables*.[9] Thus, Reinhold contributed to raising the reputation of Copernicus's numerical parameters and played a central role in the early dissemination of the latter's work. This also fostered the reception of Copernicus's geometrical models.[10]

[6] Lynn Thorndike, *A History of Magic and Experimental Science*, vol. 5 (New York: Columbia University Press, 1941), chap. 17; Stefano Caroti, "Melanchthon's Astrology," in *"Astrologi Hallucinati:" Stars and the End of the World in Luther's Time*, ed. Paola Zambelli (Berlin-New York: Walter de Gruyter, 1986); Sachiko Kusukawa, *The Transformation of Natural Philosophy: The Case of Philip Melanchthon* (Cambridge: Cambridge University Press, 1995); Dino Bellucci, *Science de la nature et Réformation: La physique au service de la Réforme dans l'enseignement de Philippe Mélanchthon* (Rome: Edizioni Vivere In, 1998), 219-318.

[7] Thüringer, "Paul Eber (1511-1569);" Claudia Brosseder, Im Bann der Sterne: Caspar Peucer, Philipp Melanchthon und andere Wittenberger Astrologen (Berlin: Akademie), 2004; Christoph Meinel, "Certa deus toti impressit vestigia mundi: Melanchthons Naturphilosophie," in Der Humanist als Reformator: Über Leben, Werk und Wirkung Philipp Melanchthons, ed. Michael Fricke (Leipzig: Evangelische Verlagsanstalt, 2011); Karin Reich, "Philipp Melanchthon im Dialog mit Astronomen und Mathematikern: Ausgewählte Beispiele," in *Mathematik und Naturwissenschaften in der Zeit von Philipp Melanchthon*, ed. Franz Fuchs (Wiesbaden: Harrassowitz, 2012), 27-58; Heinz Kathe, *Die Wittenberger Philosophische Fakultät 1502-1817* (Köln-Weimar-Wien: Böhlau, 2002), chap. 2.

[8] Denis Savoie, "La diffusion du Copernicianisme au XVI[e] siècle: Les Tables Pruténiques," *L'Astronomie* 111 (1997): 45-50.

[9] Richard L. Kremer, "Kepler and the Graz Calendar Makers: Computational Foundations for Astrological Prognostication," in Johannes Kepler: From Tübingen to Żagań, ed. Richard L. Kremer and Jarosław Włodarczyk (Warsaw: Instytut Historii Nauki PAN, 2009).

[10] Cf. Omodeo, *Copernicus in the Cultural Debates of the Renaissance,* chap. 2. On Reinhold see Owen Gingerich, "Reinhold, Erasmus," in *Dictionary of Scientific Biography* XI, ed. Charles Coulston Gilliespie (New York: Scribner, 1975); Owen Gingerich, "Erasmus Reinhold and the Dissemination of Copernican Theory," in Owen Gingerich, *The Eye of Heaven: Ptolemy Copernicus, Kepler* (New York: American Institute of Physics, 1993).

In spite of the historical relevance of these aspects, the fact that Reinhold has been mainly considered from the point of view of "Copernicanism" has often obscured other dimensions of his life and work. For instance, a thorough study of the documents relative to his activity as a professor and as a commentator is still missing. Luckily, Peter Barker and Isabelle Pantin have opened up the wider investigation of Reinhold's achievement in recent publications.[11] This essay continues this broader engagement with Renaissance astronomical culture and the place occupied by Reinhold in this context. We will focus here on his commentaries.[12]

3. Reinhold's commentaries

Commentary is a typical product of medieval and early modern university teaching. Generally speaking, professors were expected to deliver lectures (*lectiones*) in which, relying on authoritative texts, they instructed their students in different subjects. Digressions were part of the teaching practice.[13] Thereby lecturers were able to expand on topics that they deemed relevant to the students. Hence, they had certain autonomy and freedom while basing their classes on acknowledged sources, such as the *corpus Aristotelicum* and the *corpus Galenicum* in natural philosophy and medicine. Medieval and Renaissance commentaries offer a clue to such teaching practices. In some cases commentaries could even grow to hypertrophy resulting into volumes many times as big as the original source. For instance, late Renaissance commentaries on Johannes Sacrobosco's *De sphera*, the standard introduction to spherical astronomy, expanded this small-sized thirteenth-century textbook into huge works, as was the case with the commentaries of the Jesuit mathematician

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[11] Peter Barker, "The Hypotyposes orbium coelestium (Strasbourg, 1568)", in *Nouveau ciel, nouveau terre: La révolution copernicienne dans l'Allemagne de la Réforme, 1530-1630*, ed. Miguel Á. Granada and Edouard Mehl (Paris: Le Belles Lettres, 2009); Isabelle Pantin, "The First Phases of the *Theoricæ Planetarum* Printed Tradition (1474-1535): The Evolution of a Genre Observed through its Image," *Journal for the History of Astronomy* 43/1 (2012).

[12] This essay also complements our earlier studies on Reinhold's post-Copernican reception of Ptolemy. Cf. Omodeo and Irina Tupikova, "Post-Copernican Reception of Ptolemy: Erasmus Reinhold's Commented Edition of the Almagest, Book One (Wittenberg, 1549)," *Journal for the History of Astronomy* 44/3 (2013): 236-238.

[13] For a thought-provoking study on teaching culture at early-modern Protestant universities, see William Clark, *Academic Charisma and the Origins of the Research University* (Chicago: The University of Chicago Press, 2006).

Christophorus Clavius (1537-1612) and of the Lyon astrologer Francesco Giuntini (1523-1590). Both faced the obsolescence of *De sphera* as a textbook due to advances in geographical and astronomical knowledge. Thus, they judged it useful to enlarge and actualize the textbook.[14]

Reinhold authored commentaries on ancient, medieval and modern astronomical sources but published them only in part. Among other things, he published a students' edition of Peuerbach's *Theoricae novae planetarum* (Wittenberg, 1542) endowed with diagrams. This publication continued a well-established visual commentary tradition in astronomy. In particular, in the *Theorica* genre visualization was often seen as more important than the addition of textual comments. As Pantin explains, "diagrams were essential in the *Theoricae planetarum*, as the title of the work suggests. The word 'theorica' had two indistinguishable meanings. It could refer to a verbal description and geometrical explanation of the movements of one of the planets [...], or to diagrams representing the different circles and orbs that composed this planet's sphere."[15] Diagrams also conveyed information about the physical reality of *orbes coelestes* or heavenly spheres deputed to transport heavenly bodies such as the wandering stars (the Sun, the Moon and the "other" planets). For example, the main spheres could be made visible with black ink (Fig. 1). In this manner, the drawers of planetary diagrams indicated that eccentric or epicyclical planetary motions did not take place in a void. Rather, they were embedded in material concentric spheres. Reinhold used precisely this strategy in his edition of Peuerbach's textbook on planetary theory.[16]

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[14] Isabelle Pantin, "Francesco Giuntini et les nouveautés celestes," in *Celestial Novelties on the Eve of the Scientific Revolution, 1540-1630*, ed. Dario Tessicini and Patrick J. Boner (Florence: Olschki, 2013). For an overview of Renaissance shperae and commentaries thereupon, see Matteo Valleriani, "The Tracts of the *Sphere*: Knowledge Restructured over a Network," in *The Structures of Practical Knowledge*(Cham: Springer, 2017), 421-474.

[15] Pantin, "The First Phases," 4.

[16] Barker, "The Hypoteses oribum coelestium," 91, Fig. 2, and 94-96.

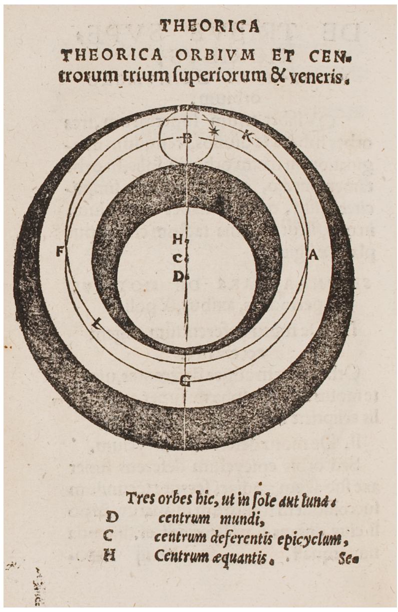

Figure 1: Planetary models in Gregor Reisch's *Margarita philosophica* (Freiburg, 1508) (left) and in a sixteenth-century edition of Georg Peuerbach's *Theoricae novae planetarum* (right).

Some of Reinhold's manuscript commentaries are still extant. A volume binding of his work-in-progress astronomical commentaries is preserved in the *Staatsbibliothek zu Berlin* under the signature "Ms. lat. fol. 391."[17] The volume is known as *Commentarius in opus Revolutionum Copernici* because it comprises a draft commentary of *De revolutionibus*, which Reinhold was never able to finish due to his untimely death. A selective transcription of the text was included in volume VIII,1 of Copernicus's *Gesamtausgabe*, on the reception of Copernicus (*Receptio Copernicana*).[18]

The Copernicus commentary comprises glosses and diagrams referring to classical sources, in particular Ptolemy and Pliny. These commentaries are not unrelated to Copernicus as they concern planetary issues crucial for a correct understanding of *De revolutionibus*. Since the aforementioned *Receptio Copernicana* volume only comprises transcriptions of commentaries that are explicitly related to Copernicus's text, we would like to briefly expand on some of the unpublished passages on Pliny. Such commentaries are an instance of the application of mathematics to philology. In a certain sense they are an early example of the *internalist* history of science. In fact, Reinhold applied his technical knowledge to the

[17] http://echo.mpiwg-berlin.mpg.de/ECHOdocuView?mode=imagepath&url=/mpiwg/online/permanent/library/MCE8830N/pageimg (December 4, 2013).
[18] Nicolaus Copernicus, *Receptio Copernicana: Texte zur Aufnahme der copernicanischen Theorie*, ed. Heribert M. Nobis and Anna Maria Pastori (Berlin: Akad.-Verl., 2002).

interpretation of a classic and to the reconstruction of ancient mathematical theories using (early) modern means.

While the use of mathematical diagrams to study Ptolemy appears justified considering the nature of the original text, their application to Pliny is not at all obvious. Reinhold's quite anachronistic approach is revealing of the centrality of the by mathematical disciplines to his academic environment. His reading of the second book of the *Natural History* is informed by the cultural guidelines of a center such as Wittenberg in which mathematical proficiency and philological training had become a fundamental pedagogical assets. Reinhold saw himself as a prosecutor of the philological-mathematical tradition launched by the Johannes Regiomontanus (1436-1476). Reinhold prompted his students to follow the example of the great humanistic mathematician—"*Regiomontanum imitemur*"—in his *Oratio de Iohanne Regiomontano*, which he gave at Wittenberg in 1549 to mark the conferral of eight master's degrees.[19] On that occasion, Reinhold praised Regiomontanus as a universal scholar, as somebody who travelled across the borders of Germany, Italy and Hungary and mastered two "foreign languages," Greek and mathematics. In his eyes, Regiomontanus's most important scholarly endeavor was the restoration of mathematical and classical studies, seen as two sides of the same coin. Against the background of this mathematical-humanistic legacy, Rheinold's mathematical philology is a natural complement to Melanchthon's cultural program. It can be aptly seen as a Lutheran implementation of the humanistic Renaissance of mathematics.[20]

4. Annotations on Pliny's Planetary Theory

Reinhold's manuscript pages on Pliny bear witness to his efforts to make sense of the planetary theories presented in the second book of the *Natural History*. This is the book specifically dealing with cosmological and astronomical themes, but also with meteorology. Reinhold drew interpretative diagrams and annotated schematic

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[19] Erasmus Reinhold, *Oratio de Iohanne Regiomontano mathematico*, in *Selectissimarum orationum clarissimi viri Domini Philippi Melanchthonis*, tome 3 (Erphurdiae: Excussit Gervasius Sturmer, 1551), [ff. 157*r*-172*v*], [f. 160*r*] and [f. 169*v*]: "Imitemur [...], quantum possumus, eius studia et sedulitatem. Denique has ipsas artes, quas illustravit, amemus et magnificiamus."

[20] We borrow this concept from Paul Lawrence Rose, *The Italian Renaissance of Mathematics: Studies on Humanists and Mathematicians from Petrarch to Galileo* (Genève: Droz, 1975).

explanations that were meant to help interpret difficult passages such as the following one taken from *Natural History* II, 6, 39-41:

> The course of these stars [the two inferior planets] also is particular, and not shared by those above-mentioned [the two superior planets]: those are often observed to be a quarter or a third of the heaven away from the Sun and travelling against the Sun, and they all have other larger circuits of full revolution [...].[21]

... or the following passage (*Natural History* II 12, 59-61):

> The three planets whose positions we have stated to be above the Sun are occulted when they set and are never more than 11 degrees separate from the Sun at dawn when they rise. Afterwards they retire from contact with his rays, and make their morning or 'first' stations in a triangle 120 degrees away, and subsequently their evening rising opposite 180 degrees away, and again approaching from the other side, make their evening or 'second' stations 120 degrees away, till the Sun overtaking them at 12 degrees obscures them—this is called the evening setting. The planet Mars being nearer feels the Sun's rays even from its quadrature, at an angle of 90 degrees, which has given to his motion after each rising the name of 'first' or second 'ninety degree.' At the same time Mars remains stationary in the signs of the zodiac for periods of six months (otherwise having a two months period), whereas Jupiter and Saturn spend less than four months in each station. The two lower planets (Mercury and Venus) are similarly obscured at their evening conjunction, and when left by the Sun make their morning rising the same number of degrees away, and from the further limits of their distance follow the Sun and when they have overtaken him are hidden in their morning setting and pass away. Then they rise in the evening at the same distance apart, as far as the limits we have stated. From these they pass backward to the Sun, and disappear in their evening setting. The planet Venus actually makes two stations, after each rise, from the furthest limits of her distance. Mercury's stations have too short a period to be perceptible.[22]

[21] Pliny the Elder, *Natural History: Books 1-2* [1938] (Cambridge, MA: Harvard University Press, 1991), 193.
[22] Ibid., 207-211, translation revised.

For our present purposes, it is enough to stress the technical difficulty of these passages and their call for an astronomical explanation. Reinhold confronted them in a section of the Berlin manuscript entitled “Tables relative to Pliny’s mathematical sections” (*Tabulae in capita mathematica Plinii*).[23] This indication clearly refers to the visual dimension of the commentary, namely the diagrams, or *tabulae*.

Let us take into consideration the beginning of Reinhold’s explanation, addressing the rising (*ortus*) and setting (*occasum*) of the wandering stars. First, he provides a simple diagram representing the deferent circle of any planet’s epicycle inscribed in the circle of the zodiac (Fig. 2).

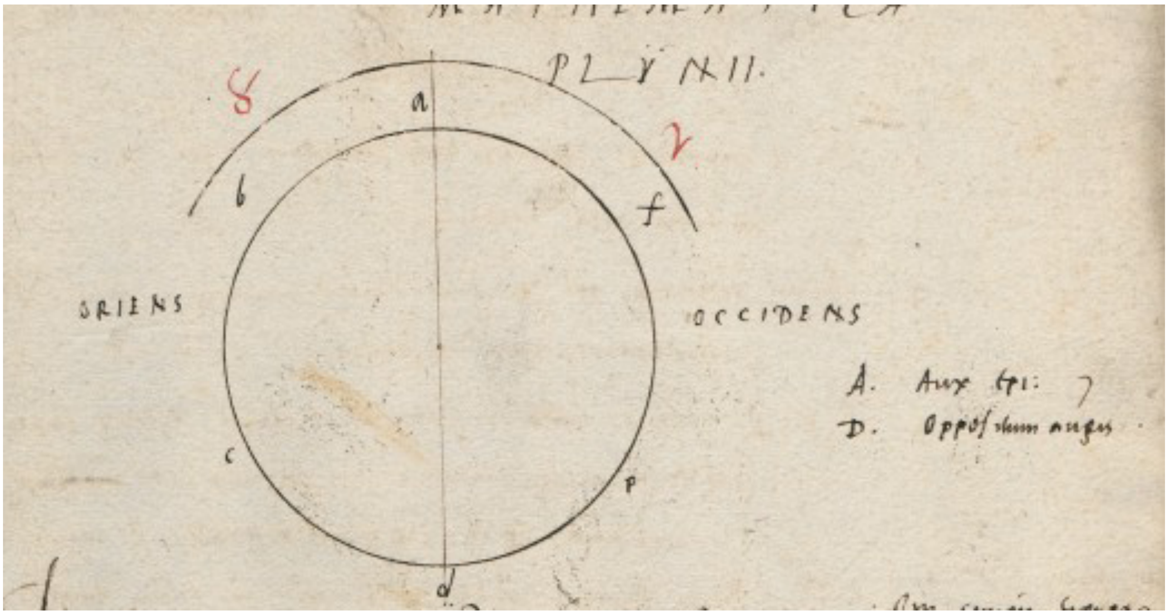

Figure 2: Reinhold’s commentary on Pliny displaying a deferent inscribed in the Zodiac, Stt Ms. lat. fol. 391, 295*r*.

The diagram is accompanied by three axioms:

Primum sic imaginandum est ἐπικίκλον moveri s[ecundum] seriem signorum in superiori sui parte. Con[tra] vero in inferioris.
Secundo in 3 superioribus ea est proportio motus in ἐπι[κίκλῳ] ad <Solem> [ut], in <coniunctione> Solis et planetae ali[cuius] hor[um] 3 media, Planeta iste sit in auge ἐπι[κίκλου]. In oppositione vero est in opposito augis remoto

[23] [Erasmus, Reinhold], *Commentarius in opus Revolutionum Copernici*, Staatsbibliothek zu Berlin, coll. Ms. lat. fol. 391, 295*r*.

Tertio in duobus inferioribus observandum est q[uod] semper ambiunt solem. Id est Sol [con]sisti prope super augem ἐπι[κίκλου] cum eadem est linea medii motus <Solis> <Veneris> et <Mercurii>

That is:

1. The epicycle moves along the series of the signs in its superior part and in the contrary direction in the inferior.
2. Relative to the three superior [planets], their epicyclical motion has such a ratio to the Sun that, in the conjunction between the mean Sun and any of those three [planets], the planet is in the apsis of the epicycle, [whereas] in opposition it is in the opposite apsis.
3. In the case of the two inferior [planets], they always go around the Sun. Hence, the Sun is located almost above the apsis of the epicycle since the line of the mean motion of the Sun, Venus and Mercury is the same.

The first of these axioms makes explicit an aspect of the epicyclical theory concerning the apparent direction of planetary motions. To a terrestrial observer, in this case one located at the stationary center of a pre-Copernican cosmos, a planet moves eastwards (along the zodiacal signs) when it is going along the upper part of its epicycle and it moves westwards when it goes along the lower arc of the same circlet. Reinhold provides a visualization of an epicycle and its appearance to a terrestrial observer a few folios later (Fig. 4).[24] The second axiom relates to the geocentric epicyclical approximation for the elliptic obits of the superior planets. Reinhold indicates the connection between the apses and the solar theory. The third axiom refers to the motion of the inferior planets but in this case the connection with the Sun is explained using a heliocentric postulate. Reinhold refers to a model in which Mercury and Venus encircle the Sun while the Earth remains immobile at the center of the system. This passage on the geo-heliocentric paths of the inferior planets ought to be connected with another well-known passage of the Copernicus commentary, in which Reinhold sketches a rough geo-heliocentric translation of the

[24] [Reinhold], *Commentarius in opus Revolutionum Copernici*, 296*v*.

Copernican theory for Jupiter.[25] The reference to the geo-heliocentric model for the inferior planets in the Pliny commentary reinforces a opinion shared by Renaissance contemporaries of Reinhold, namely that he was interested in testing various planetary hypotheses, among them geo-heliocentric possibilities.

Reinhold's diagram and three axioms are followed by a schema detailing how they can be applied to various cases (Fig. 3). With the help of this explanation one can determine at what point of its deferent any given celestial body rises in the East (*oriuntur ortu*), either in the morning (*matutino*) or in the evening (*vespertino*) (of course the Sun always rises in the morning and from the East), and at what point it appears in the West (*oriuntur ocassum*), either in the morning or in the evening. Reinhold subsequently expands on how to derive the direction of planetary motions, stations and retrogradations, from the epicyclical modeling (Fig. 4).

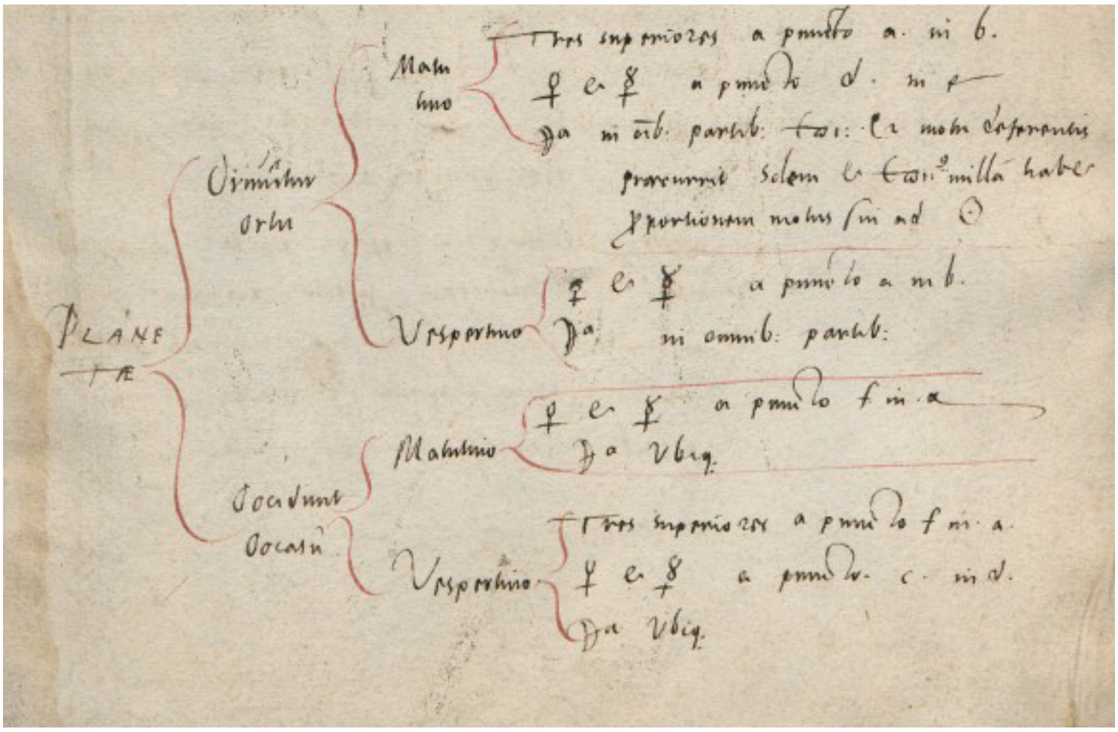

Figure 3: Reinhold's schema about the oriental and occidental rise and setting of the wandering stars.

[25] Ibid., 145*v*. See Aleksander Birkenmajer, "Le commentaire inédit d'Erasme Reinhold sur le *De revolutionibus* de Nicolas Copernic," in *La science au seizième siècle* (Paris: Hermann, 1960); Omodeo and Irina Tupikova, "Post-Copernican Reception of Ptolemy," 236-238.

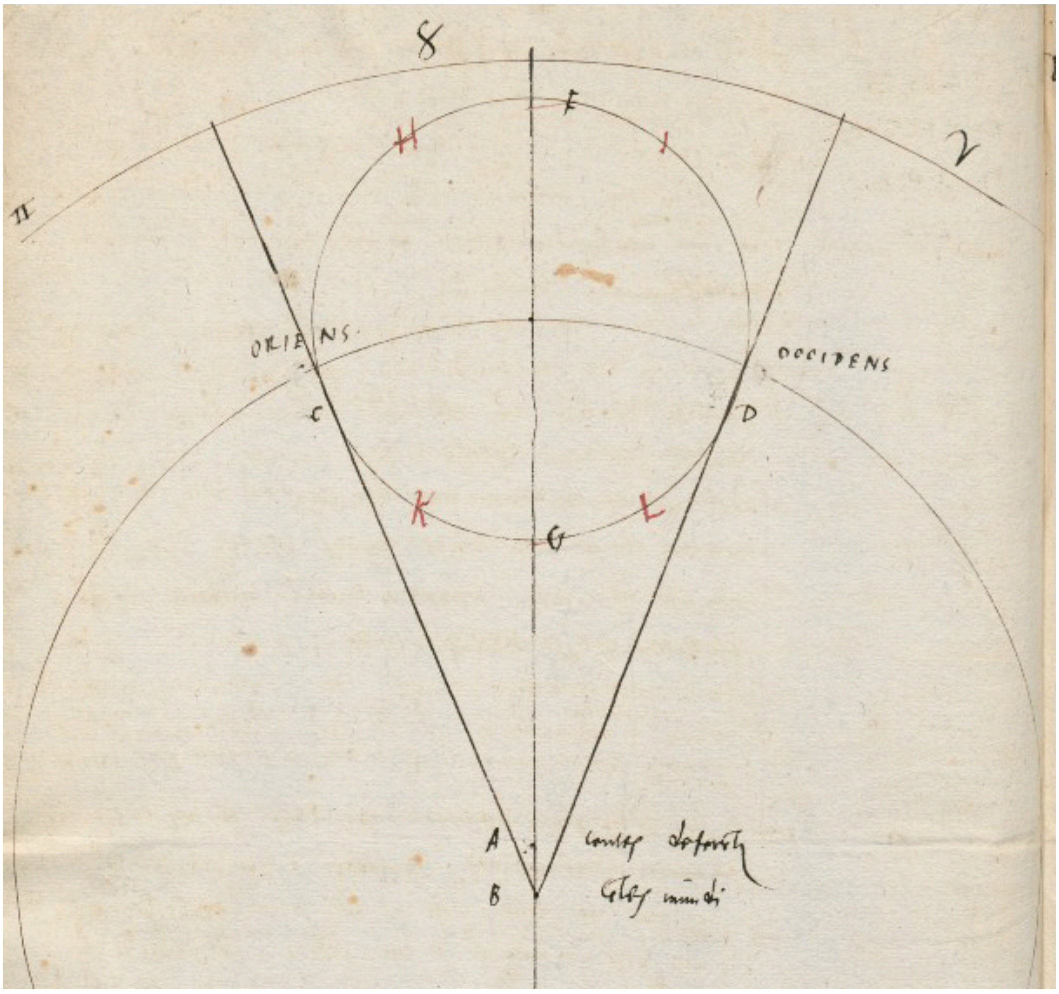

Figure 4: Ms. lat. fol. 391, 296*v* displaying an epicycle as seen from the centrum mundi B.

5. Some Remarks Concerning the Authorship of the Commentary on Pliny

Reinhold was not the first Renaissance scholar to encounter the intricacies of the interpretation of Pliny's astronomical sections. Because the authoritative editions of this classical work provided no diagrams, the reader was given no visual aid to understand the technicalities of the mathematical astronomy presupposed by Pliny. For instance, although the elegant 1525 Venetian edition based on Ermolao Barbaro (1454-1493) underlined the presence of figures in the title page (*addito... figuris... ad singulorum librorum materiam aptissimis*), these were decorative instead of explanatory. The second book in particular features no astronomical diagrams, apart from a very elementary illustration of the Aristotelian cosmos at the beginning of the section (Fig. 5).


LIBER SECVNDVS I

CAII PLINII SECVNDI NATVRALIS HISTORIÆ LIBER SECVNDVS

An Finitus Sit Mundus, Et An Vnus. CA. I.

MVNDVM, ET HOC QVOD nomine alio cælum appellari libuit, cuius circũflexu teguntur cũcta: numen eſſe credi par eſt æternum, immenſum, neq; genitum, neq; interiturum unquam. Huius extera indagare nec intereſt hominum, nec capit humanæ coniectura mentis. Sacer eſt, æternus, immenſus, totus in toto, immo uero ipſe totum, finitus, ac infinito ſimilis. Omnium rerum certus, & ſimilis incerto. Extra, intra, cuncta complexus in ſe, idéq; rerum naturæ opus, & rerum ipſa natura. Furor eſt menſuram eius animo quoſdam agitaſſe, atq; prodere auſos. Alios rurſus occaſione hinc ſumpta, aut his data innumerabiles tradidiſſe mũdos, ut totidem rerum naturas credi oporteret. Aut ſi una omnes incubarent, totidem tamen ſoles, totidemq; lunas, & cætera etiam in uno & immenſa, & inumerabilia ſydera, quaſi nõ eadem quæſtione ſemper in termino cogitationis occurſura deſyderio finis alicuius. Aut ſi hæc infinitas naturæ omniũ artifici poſſit aſſignari, non illud idem in uno facilius ſit intelligi tanto præſertim opere. Furor eſt, pfecto, furor, egredi ex eo, & tanq̃ interna eius cuncta plane iam ſint nota, ita ſcrutari extera, quaſi uero menſuram ullius rei poſſit agere, qui ſui neſciat, aut mens hominis uidere quæ mundus ipſe non capiat.

Figure 5: A simple Aristotelian cosmological diagram included in the elegant Venetian edition of Pliny's *Natural History* printed by Sessa & Serena (1525).

Jacob Ziegler (1470-1549) worked on a detailed and technical explanation of Pliny's second book. His commentary was printed in 1531. Ziegler was a German astronomer, geographer and Erasmian humanist who lived in many German and Italian provinces, as well as in Moravia and Hungary. He was a professor of theology in Vienna for a short period. Heinrich Petri (1508-1579) published Ziegler's commentary on the astronomical issues of the second book of the *Natural History* in Basel. That same printer also contributed to the astronomical and cosmological culture of his age with publications such as the second edition of Copernicus's *De revolutionibus* together with the third edition of Rheticus's *Narratio prima* (1566) and Nicholas Cusanus's *Opera* (1567). Ziegler was acquainted with the latter's *Docta ignorantia,* which he made reference to in a passage about the doctrine of terrestrial motion (Ziegler 1531, 49). As to planetary theory, Ziegler provided accurate diagrams which possibly served as a basis for Reinhold's ones (Fig. 6 and Fig. 7).

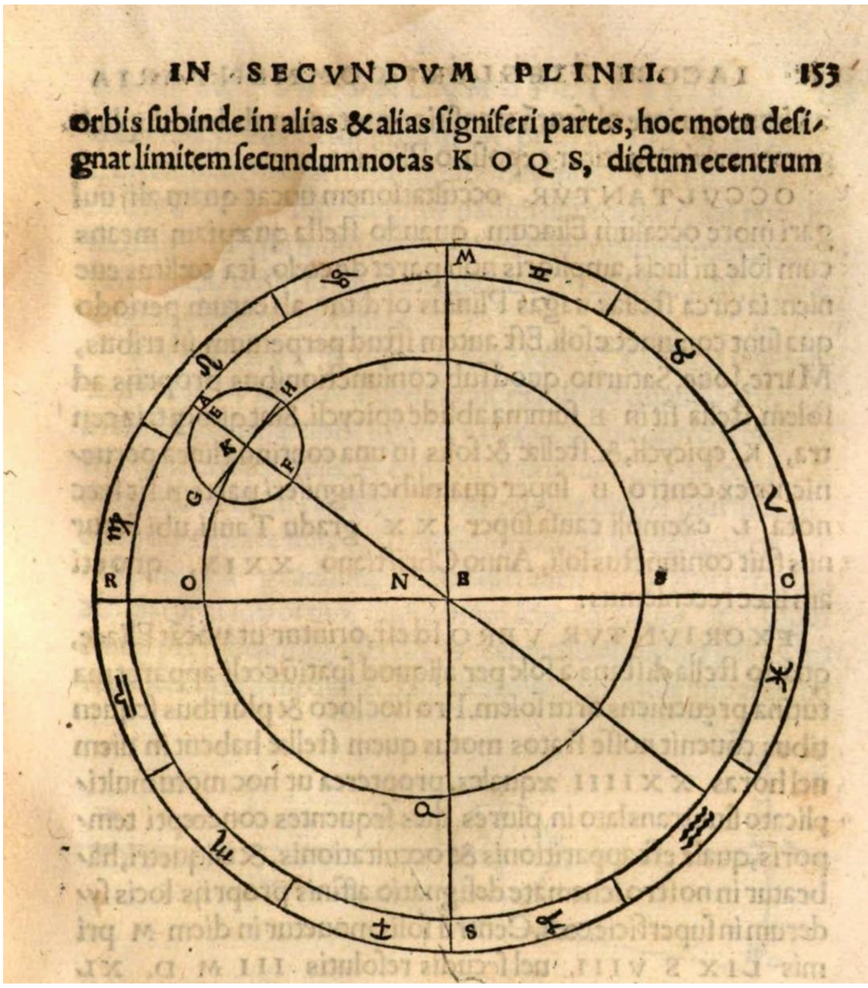

Figure 6: Ziegler's epicyclical diagram in his commentary to the second book of Pliny's *Natural History* (1531, 153).

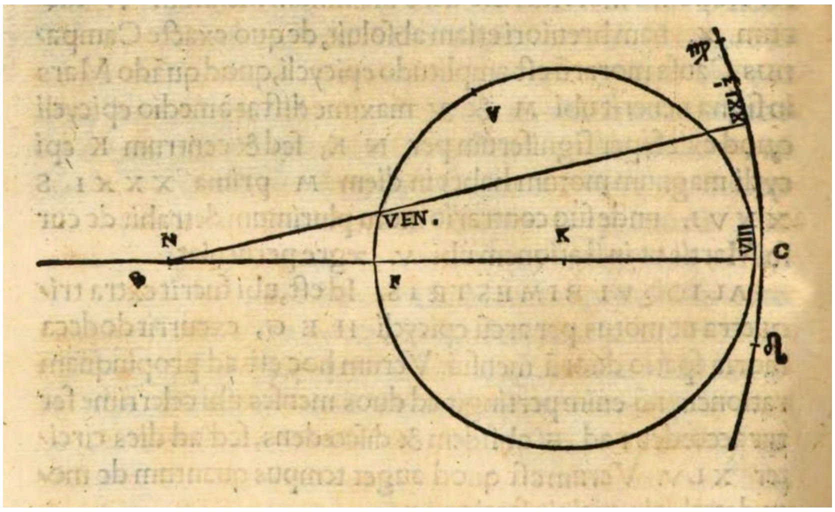

Figure 7: Ziegler's epicyclical diagram for Venus against the background of the Zodiac (1531, 164).

For our purposes, the commentary to the second book of the *Natural History* authored by Reinhold's Wittenberg professor Jakob Milichius (1501-1559) is even more relevant. Milichius was a learned Erasmian humanist who had studied in Freiburg and Wien and moved to Melanchthon's Wittenberg in 1524, where he lectured on Pliny's work, on mathematics, and later on medicine as well. Rheticus succeeded him as the chair of lower mathematics in 1536.[26] The commentary on Pliny stemmed from Milichius's classes. It was first printed by Peter Brubach in Hagenau in 1535. Because it was reprinted four times in the following four decades it should be seen as a successful work. Milichius's explanations on Pliny's section about comets were to influence the German discourse on comets in the sixteenth and seventeenth centuries.[27] However, this publication is less elegant than Ziegler's. In particular, Milichius's illustrations for Pliny's planetary theory included in the first edition look rough (Fig. 8)

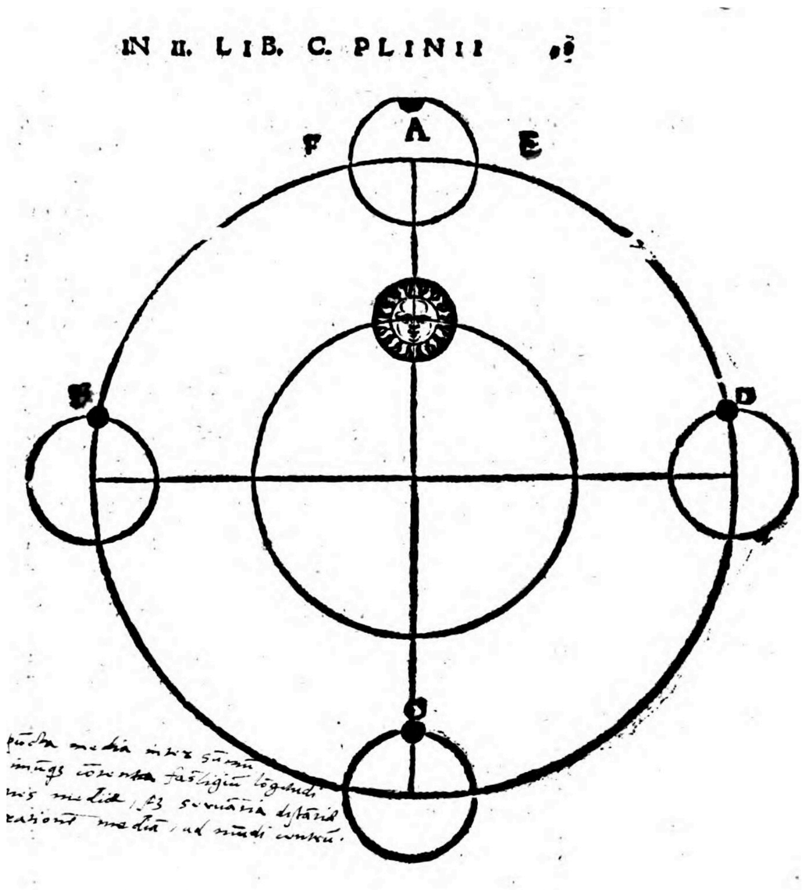

Figure 8: Milichius's rough diagram for epicyclical planetary motions relative to *Natural History* II 15, in the first edition of his Pliny commentary (1535, 38*r*).

[26] Kathe, *Die Wittenberger Philosophische Fakultät*, 114-115.

[27] Marion Gindhart, *Das Kometenjahr 1618: Antikes und zeitgenössisches Wissen in der frühneuzeitlichen Kometenliteratur des deutschsprachigen Raumes* (Wiesbaden: Dr. Ludwig Reichert, 2006), fn. 12.

A diagram that appears in folio 37 *recto* (Fig. 9) indicates the apparent direct and retrograde motion of any planet transported by an epicycle. If one closely looks at it, one can clearly detect its connection with Reinhold's epicyclical diagram (Fig. 4).

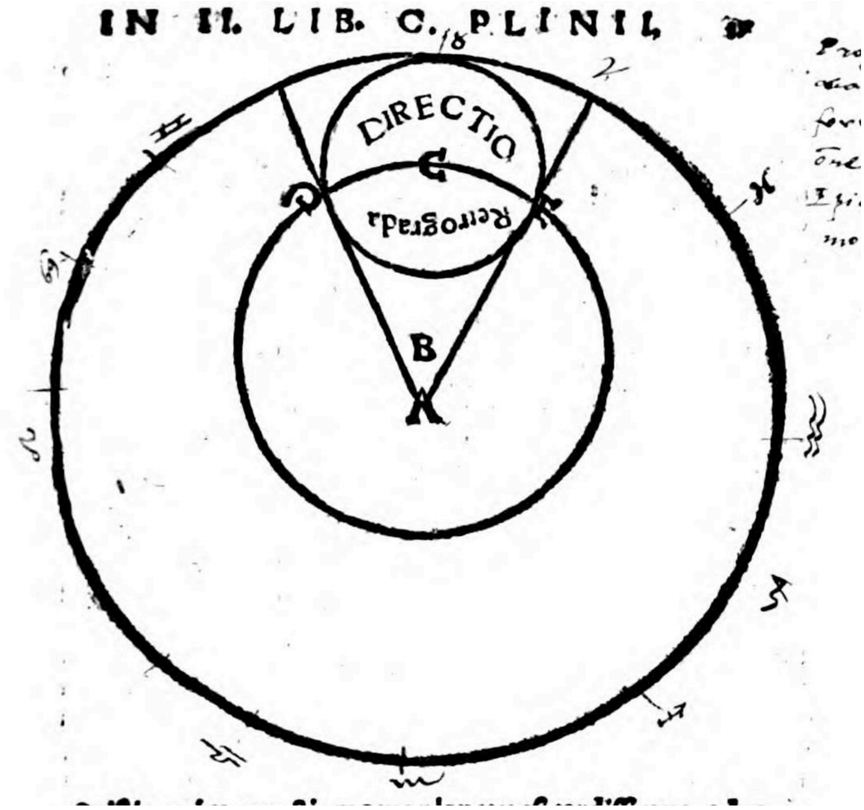

Figure 9: Direct and retrograde planetary motions by Milichius (1535, 37*r*)

The relationship between this diagram and Reinhold's manuscript is confirmed by its reworking in a later edition of Milichius's Pliny (Frankfurt/Main, 1543) (Fig. 10). Not only is this diagram exactly the same as in Reinhold's papers, but it is also accompanied by the same schematic table about the rising and setting of the various wandering stars (Fig. 11). Hence a question arises regarding the authorship of Milichius's printed diagrams and the schemas for Pliny and Reinhold's ones. In order to dispel this problem of authorship, it would be necessary to go into a textual analysis and also take into account the in-between edition of Milichius's commentary (Schwäbisch Hall, 1938). But here is not the place to accomplish this inquiry. For the time being we would like to mention two possibilities. First, Reinhold might have copied and reworked the diagrams of his professor and colleague Milichius into his manuscript. Reinhold's annotations are schematic (in the form of axioms or lists of concise statements) whereas Milichius' commentaries are discursive. As an alternative, Reinhold's manuscript might prove his involvement in Milichius's edition. It is thinkable that he refined Milichius's diagram and additionally drew the table of risings and settings that were in the embellished later edition of the Pliny commentary.

Such practices of collaborative editing were common in Melanchthon's circle. For instance, Reinhold corrected and improved the astronomical part of the *Initia doctrinae physicae* (1549), which was itself the result of a collaboration between Melanchthon and the philosophy professor Paul Eber (1511-1569).[28] As far as commentary practices are concerned, the continuity between manuscript and printed culture should be emphasized here—we will also stress this aspect in relation to the reception of Reinhold's Ptolemy commentaries. In an age of transition to a new medium and novel forms of knowledge circulation, commentary practices deployed in the edition of texts heavily relied on manuscript practices that were still widespread. In turn, printed texts could have added manuscript commentaries that were copied from many versions and thus had a wide dissemination.

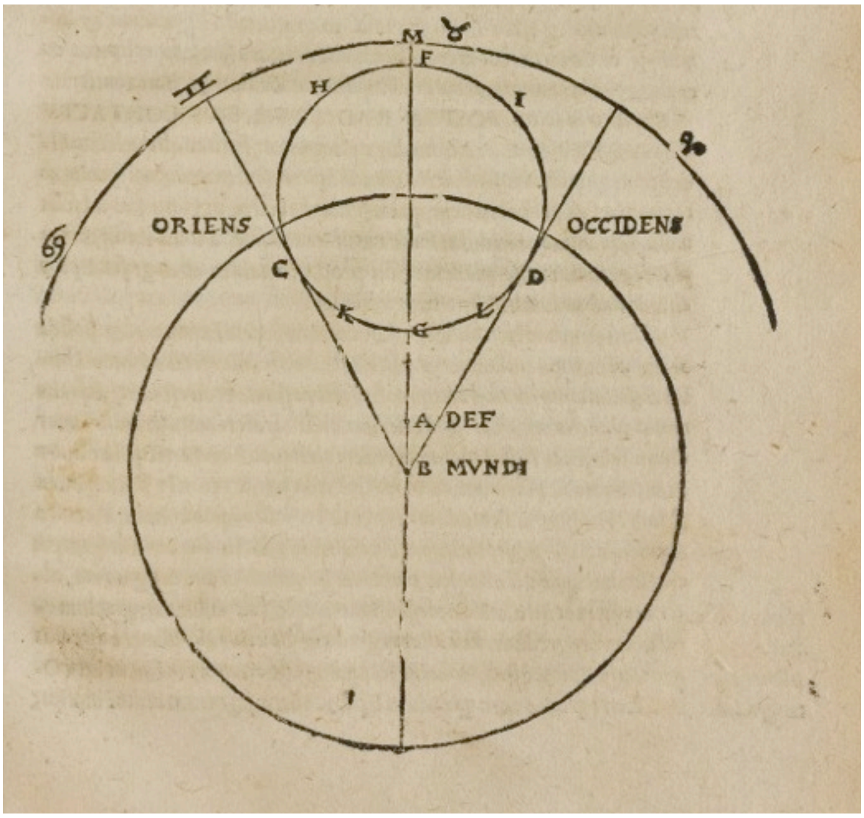

Figure 10: Epicyclical diagram in Milichius (1543), 54.

[28] Thüringer, "Paul Eber (1511-1569)."

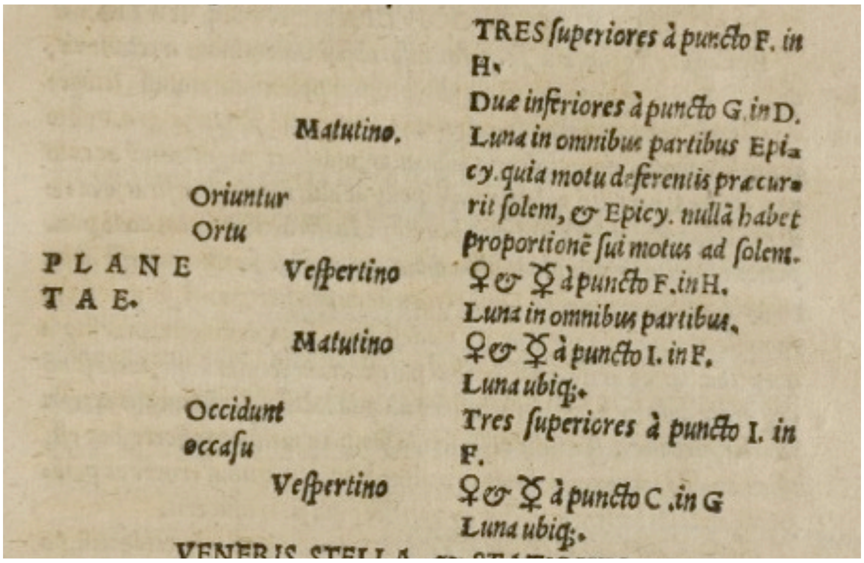
PLANETAE.
Oriuntur Ortu
Matutino. TRES superiores à puncto F. in H.
Duæ inferiores à puncto G. in D.
Luna in omnibus partibus Epicy. quia motu deferentis præcurrit solem, & Epicy. nullã habet proportionẽ sui motus ad solem.
Vespertino ♀ & ☿ à puncto F. in H.
Luna in omnibus partibus.
Occidunt occasu
Matutino ♀ & ☿ à puncto I. in F.
Luna ubiq;.
Tres superiores à puncto I. in F.
Vespertino ♀ & ☿ à puncto C. in G
Luna ubiq;.

Figure 11: Table relative to planetary raisings and settings according in Milichius (1543), 57.

6. Reinhold's Commented Edition of the *Almagest*

If Pliny's second book needs to be explained through mathematical-astronomical considerations and planetary diagrams, Ptolemy's *Almagest* requires not only textual comments but graphic integrations as well. In a recent essay dealing with the first book of the *Almagest*, we felt compelled to construct diagrams in order to visualize the geocentric arguments to understand them better.[29] The modern editions of reference, such as Toomer's English translation (Ptolemy 1983), do not provide graphic support for the arguments of the first book, although the details that Ptolemy discusses are tiny and would benefit from such support. We cannot establish with certainty whether the lack of diagrams is due to an incomplete transmission of the *Almagest* or rather whether this aspect has to be traced back to the original text. If Ptolemy really avoided any graphical support for the cosmological considerations of *Almagest* book one, this might be explained either as an aspect of the special methodological tradition he belonged to, or as the consequence of the highly developed spatial imaginativeness proper to professional astronomers of his time.[30] As far as Renaissance editions before Reinhold are

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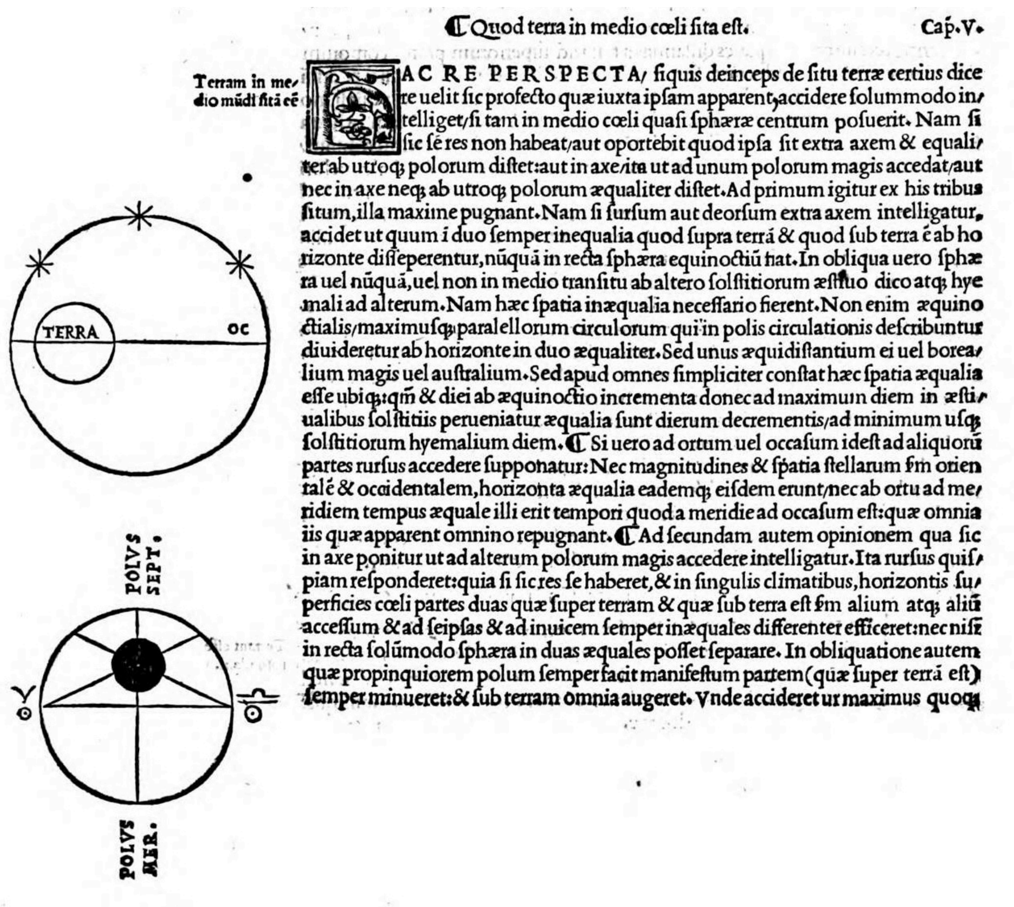
[29] Pietro D. Omodeo and Irina Tupikova, "Cosmology and Epistemology: A Comparison between Aristotle's and Ptolemy's Approaches to Geocentrism," in *Spatial Thinking and External Representation: Towards a Historical Epistemology of Space* ed. Matthias Schemmel (Berlin: Edition Open Access, 2016), 145-174.
[30] Olaf Pedersen has endowed his *modern commentary* of the *Almagest* with apt diagrams. Cf. Pedersen, *A Survey of the Almagest* (Odense: Odense University Press, 1974), pp. 35-42.

concerned, either they were endowed with no diagrams relative to cosmological part of the first book (1515),[31] or they were so poor that they did not really help understanding the text (1528) (Fig. 12).[32] Only Theon's Greek commentary, printed together with the *editio princeps* of the *Almagest,* included a few explanatory diagrams, some of which were to be picked up by Reinhold in his 1549 edition (Fig. 13).[33] The manuscript of the *Almagest* used for this edition belonged to Regiomontanus and had been acquired after his death by Johannes Walder (Valderus), owner of a printing *officina* in Basle. This manuscript was published in 1538 under the supervision of a professor for the Greek literature in Wien, Simon Grynaeus (1493-1541). It appeared together with Theon's commentary, prepared by the humanist Joachim Camerarius (1534-1598).[34]


Quod terra in medio cœli ſita eſt. Cap. V.

Terram in medio mūdi ſitā eē

HAC RE PERSPECTA, ſiquis deinceps de ſitu terræ certius dicere uelit ſic profecto quæ iuxta ipſam apparent, accidere ſolummodo intelliget, ſi tam in medio cœli quaſi ſphæræ centrum poſuerit. Nam ſi ſic ſe res non habeat, aut oportebit quod ipſa ſit extra axem & equaliter ab utroq; polorum diſtet: aut in axe, ita ut ad unum polorum magis accedat, aut nec in axe neq; ab utroq; polorum æqualiter diſtet. Ad primum igitur ex his tribus ſitum, illa maxime pugnant. Nam ſi ſurſum aut deorſum extra axem intelligatur, accidet ut quum ī duo ſemper inequalia quod ſupra terrā & quod ſub terra ē ab horizonte diſſeperentur, nūquā in recta ſphæra equinoctiū fiat. In obliqua uero ſphæra uel nūquā, uel non in medio tranſitu ab altero ſolſtitiorum æſtiuo dico atq; hyemali ad alterum. Nam hæc ſpatia inæqualia neceſſario fierent. Non enim æquinoctialis, maximuſq; paralellorum circulorum qui in polis circulationis deſcribuntur diuideretur ab horizonte in duo æqualiter. Sed unus æquidiſtantium ei uel borealium magis uel auſtralium. Sed apud omnes ſimpliciter conſtat hæc ſpatia æqualia eſſe ubiq;: qm̄ & diei ab æquinoctio incrementa donec ad maximum diem in æſtiualibus ſolſtitiis perueniatur æqualia ſunt dierum decrementis, ad minimum uſq; ſolſtitiorum hyemalium diem. Si uero ad ortum uel occaſum ideſt ad aliquorū partes rurſus accedere ſupponatur: Nec magnitudines & ſpatia ſtellarum ſm orientalē & occidentalem, horizonta æqualia eademq; eiſdem erunt, nec ab ortu ad meridiem tempus æquale illi erit tempori quod a meridie ad occaſum eſt: quæ omnia iis quæ apparent omnino repugnant. Ad ſecundam autem opinionem qua ſic in axe ponitur ut ad alterum polorum magis accedere intelligatur. Ita rurſus quiſpiam reſponderet: quia ſi ſic res ſe haberet, & in ſingulis climatibus, horizontis ſuperficies cœli partes duas quæ ſuper terram & quæ ſub terra eſt ſm alium atq; aliū acceſſum & ad ſeipſas & ad inuicem ſemper inæquales differenter efficeret: nec niſi in recta ſolūmodo ſphæra in duas æquales poſſet ſeparare. In obliquatione autem quæ propinquiorem polum ſemper facit manifeſtum partem (quæ ſuper terrā eſt) ſemper minueret: & ſub terram omnia augeret. Vnde accideret ur maximus quoq;

Figure 12: Illustrations in *Almagest*, book one, in the 1528 Venetian edition.

[31] Claudius Ptolemy, *Almagestum* (Venetiis: Liechtenstein, 1515).
[32] Claudius Ptolemy, *Almagestum sei Magne Constructionis Mathematicae…Latina donatum lingua ab Georgio Trapezuntio* (Venetia: Iunta,1528).
[33] Theon of Alexandria, Εἰς τοῦ Πτολεμαίου μεγάλην σύνταξιν ὑπομνημάτων βιβλ. ιᾱ (=XI) (Basle, 1538).
[34] Karl Manitius, "Einleitung," to Claudius Ptolemy, *Handbuch der Astronomie*, vol. 1 [1912] (Leipzig: Teubner, 1963), XXI.

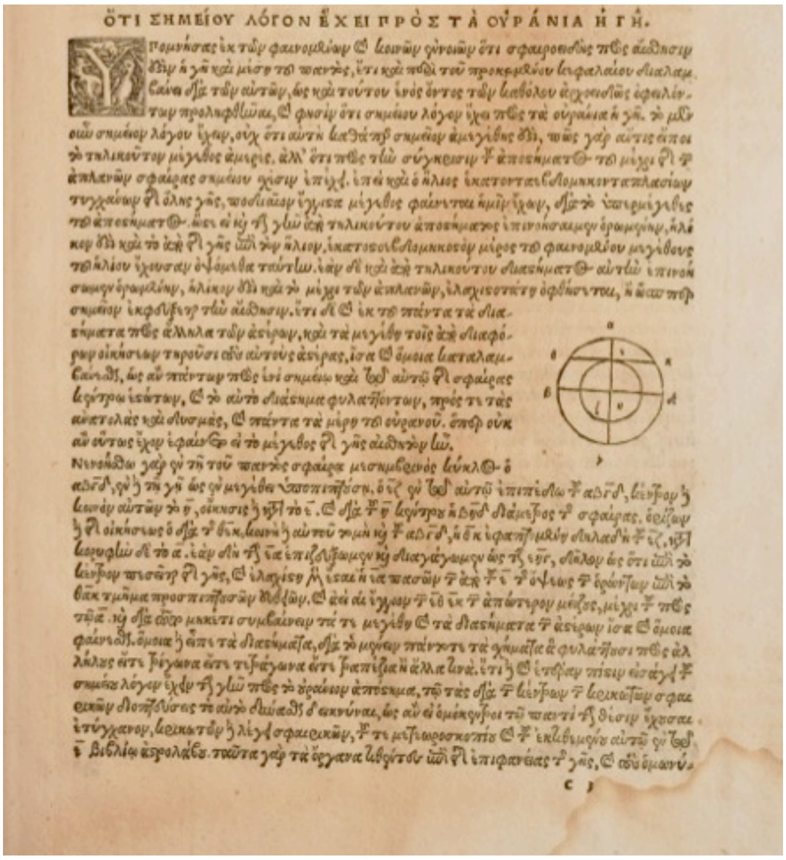

ΟΤΙ ΣΗΜΕΙΟΥ ΛΟΓΟΝ ΕΧΕΙ ΠΡΟΣ ΤΑ ΟΥΡΑΝΙΑ Η ΓΗ.

Figure 13: Diagram from the 1538 edition of Theon's commentary of Ptolemy's *Almagest*, 30.

Reinhold's commented edition of the first book of the *Almagest* was bilingual. The first part comprised the Greek text and the second one the Latin translation. The book was small in size and aimed at student use. As Reinhold stated in the prefatory letter,

> For the advantage and happiness of the public schools, I began an edition of Ptolemy's excellent work, in which the universal theory of heavenly motions is raised on its first fundaments. The present edition of the first book is aimed at making students familiar with the basics [of astronomy], which are preliminary to [a correct understanding of] the other books [of the *Almagest*]. Without any doubt, it is very useful to present young people with the sources of this discipline. Still, since the beginners are not yet conversant with the Greek language, I have added a Latin translation, for whose inaccuracy I beg the pardon of the specialists [*eruditi*]. I also hope that somebody will eventually accomplish a complete and clear translation of Ptolemy for public interest. Moreover, to help the students, I have commented and explained some difficult passages. I hope that all these efforts will be grateful to God

and that all experts will approve them. My intention is, in fact, that the youth not merely strive for the void shadow of the art [*doctrina*], but that it be made familiar with mathematics and with this art useful for human life and peace.[35]

This edition should be seen as embedded in Melanchthon's pedagogical program. Melanchthon himself authored widespread textbooks for the Faculty of the Arts covering various subjects, among them, natural philosophy (or *physica*), psychology (the doctrine of the soul), and rhetoric. He also edited Ptolemy's astrological tract, *De praedicationibus astronomicis, cui titulum fecerunt Quadripartitum... libri III*, together with Camerarius. In his Ptolemy edition, Reinhold emphasized his close connection with Melanchthon through the presence of a poem from his master at the beginning of the book.[36]

A copy of the *Ptolemaei Mathematicae constructionis liber primus,* preserved at the Herzog August Library of Wolfenbüttel, is an example of a reader's response to Reinhold's commentary. This belonged to the Swede Nicolaus Andreas Granius (1569-1631), professor of mathematics at the late-humanistic center of Helmstedt. The book is annotated throughout; several passages are underscored; headings and graphic additions are added to the diagrams in order to facilitate quick consultation (Fig. 14). All of these signs indicate the scholarly use of Reinhold's edition of the *Almagest*.

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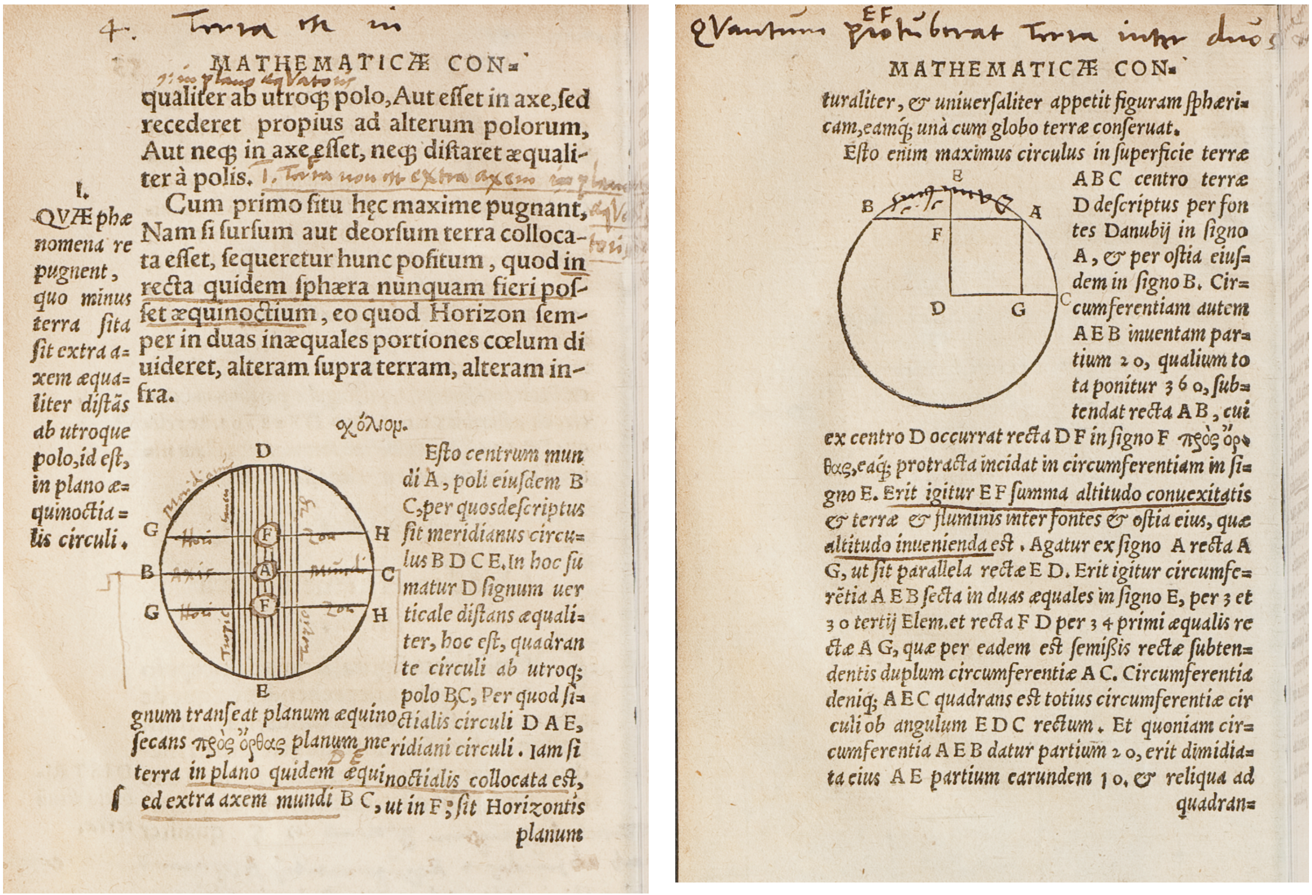
[35] Erasmus Reinhold, *Mathematicae constructionis Liber primus graece et latine editus: Additae explications aliquot locorum ab Erasmo Reinhold Salveldensi* (Wittebergae: Ex Officina Iohannis Lufft, 1549), A8*r-v*: "Itaque quod faustum et felix sit studiis publicis, incohavi editionem optimi operis Ptolemaei, in quo doctrina de motibus coelestibus universa ex primis fundamentis extructa est. Ac nunc edidi primum librum, ut haec initia fiant familiaria discentibus, quae aditum ad reliquos libros faciunt. Utilissimum autem esse deduci iuventutem ad hos doctrinae fontes, non dubium est. Et quia iuniores nondum adsuefacti sunt ad graecam lectionem, addidi et latinam interpreationem qualemcunque, de qua veniam ab eruditis peto; ac opto, ut aliqui publice utilitatis causa integram aliquando et luculentam interpretationem Ptolemaei edant. Illustravi et scholiis aliquot obscura membra, ut discentes adiuvarem. Totum hunc laborem spero et Deo gratum esse, et probaturos esse omnes sapientes. Nam hanc ob causam praecipue susceptus est, ut iuventus non inanem doctrinae umbram tantum appetat, sed ad mathemata et ad hanc doctrinam vitae hominum utilem et pacis nutricem adsuefiat." Here and in the following quotations from Latin, we have standardized the expressions and revised the punctuation and capital letters only where we deemed it useful for an easier reading of the passages.

[36] Although the authorship of this poem has been cast into doubt by recent scholarship, for our present discussion it is sufficient to mention that Reinhold ascribed it to Melanchthon. In this context, this literary preface to his edition is an example of his engagement as a member of the Melanchthonian circle. On the problems of the attribution, see Isabelle Pantin, "La lettre de Melanchthon à S. Grynaeus: Les avatars d'une apologie de l'astrologie," in Divination et controverse religieuse en France au XVI[e] siècle, ed. Robert Aulotte (Paris: Éditions Rues d'Ulm, 1987).



MATHEMATICÆ CON-

qualiter ab utroq; polo, Aut esset in axe, sed recederet propius ad alterum polorum, Aut neq; in axe esset, neq; distaret æqualiter à polis.

I.
QVÆ phænomena repugnent, quo minus terra sita sit extra axem æqualiter distãs ab utroque polo, id est, in plano æquinoctialis circuli.

Cum primo situ hęc maxime pugnant, Nam si sursum aut deorsum terra collocata esset, sequeretur hunc positum, quod in recta quidem sphæra nunquam fieri posset æquinoctium, eo quod Horizon semper in duas inæquales portiones cœlum divideret, alteram supra terram, alteram infra.

Esto centrum mundi A, poli eiusdem B C, per quos descriptus sit meridianus circulus B D C E. In hoc sumatur D signum verticale distans æqualiter, hoc est, quadrante circuli ab utroq; polo B C, Per quod signum transeat planum æquinoctialis circuli D A E, secans πρὸς ὀρθὰς planum meridiani circuli. Iam si terra in plano quidem æquinoctialis collocata est, sed extra axem mundi B C, ut in F; sit Horizontis planum

MATHEMATICÆ CON-

turaliter, & universaliter appetit figuram sphæricam, eamq; unà cum globo terræ conservat.

Esto enim maximus circulus in superficie terræ A B C centro terræ D descriptus per fontes Danubij in signo A, & per ostia eiusdem in signo B. Circumferentiam autem A E B inventam partium 20, qualium tota ponitur 360, subtendat recta A B, cui ex centro D occurrat recta D F in signo F πρὸς ὀρθὰς, eaq; protracta incidat in circumferentiam in signo E. Erit igitur E F summa altitudo convexitatis & terræ & fluminis inter fontes & ostia eius, quæ altitudo invenienda est. Agatur ex signo A recta A G, ut sit parallela rectæ E D. Erit igitur circumferẽtia A E B secta in duas æquales in signo E, per 3 et 30 tertij Elem. et recta F D per 34 primi æqualis rectæ A G, quæ per eadem est semißis rectæ subtendentis duplum circumferentiæ A C. Circumferentia deniq; A E C quadrans est totius circumferentiæ circuli ob angulum E D C rectum. Et quoniam circumferentia A E B datur partium 20, erit dimidiata eius A E partium earundem 10, & reliqua ad quadran-

Figure 14: A Copy of Reinhold's *Almagest* with annotations by Nicolaus Andreas Granius.

As an academic textbook, Reinhold's edition of Ptolemy was well received. It was reprinted several times. In Wittenberg it was issued posthumously under the varied title *Regulae artis mathematicae, graece & latine. Claudio Ptolomeo authore. Opus quidem vtile, & studiosis omnibus in hanc artem uersantibus multo necassarium. Huic addidit Erasmi Reinhold Salueldensi explicationes aliquot pulcherrimae* (1569). In Paris it was printed by Cavellat for the Collège de Cambrai at least two times, in 1556 and 1560, in a more elegant fashion but without the original Greek text. It was also accompanied by a new translation of the second book of the *Almagest* carried out by a certain "St. Gracilis." This edition, *Claudii Ptolemaei Mathematicae constructionis Liber secundus Latina interpretatione recens donatus* (Paris, [1556]), was dedicated to "Io. Magnenium medicum, et regii mathematicae scientiae professorem" who was the successor of Oronce Fine (1494-1555) as *lecteur royal* in Paris. The declared intention of this edition was to continue Reinhold's work.[37]

[37] See Ptolemy, *Mathematicae constructionis Liber secundus Latina interpretatione recens donatus* (Lutetiae: Cavellat, [1556]), 2*r*-4*r*. It should be noted that this French edition had no commentaries but comprised explanatory diagrams.

7. Reinhold's Comments on Ptolemy's Geocentric and Geostatic Arguments

Reinhold's attentive discussion of Ptolemy's geocentric and geostatic arguments in the first book of the *Almagest* is immediately interesting for the historian of astronomy aware of the importance of Wittenberg for the first dissemination of Copernicus's work. This section of the most important astronomical work from antiquity received no relevant, complementary graphical aids in early editions. By contrast, Reinhold's commentary provided a valid integration of text and graphics. We would like to consider a few instances of his use of didactic diagrams which we, in turn, will explain through new graphic representations—a sort of second-degree visual commentary that assists one to appreciate the issues at stake in Ptolemy as well as Reinhold's own engagement with his source.

7.1 First example: *sphaera recta* for an eccentric Earth on the equatorial plane

In Chapter I 5 of the *Almagest* (or I 4 according to Reinhold's non-standard chapter numbering), Ptolemy presented a series of astronomical arguments in support of the central position of the Earth in the middle of the universe. Here we will limit ourselves to the first hypothetical case Ptolemy considered in his demonstration *ad absurdum* that the Earth is not on the rotational axis of the universe but equidistant from both poles (*Almagest* I H17, p. 41):[38]

> If we imagined [the Earth] removed towards the zenith or the nadir of some observer then, if he were at *sphaera recta*, he would never experience equinox, since the horizon would always divide the heavens into two unequal parts, one above and one below the Earth; if he were at *sphaera obliqua*, either, again, equinox would never occur at all, or [if it did occur], it would not be at a position halfway between summer and winter solstices, since these intervals would necessarily be unequal,

[38] For a more detailed treatment, see our paper "Post-Copernican Reception of Ptolemy" (2013).

> because the equator, which is the greatest of all parallel circles drawn about the poles of the [daily] motion, would no longer be bisected by the horizon; instead [the horizon would bisect] one of the circles parallel to the equator, either to the north or to the south of it. Yet absolutely everyone agrees that these intervals are equal everywhere on Earth, since [everywhere] the increment of the longest day over the equinoctial day at the summer solstice is equal to the decrement of the shortest day from the equinoctial day at the winter solstice.[39]

Ptolemy separately considers two possible positions of observation, one at equator (*sphaera recta*) and another at arbitrary latitude (*sphaera obliqua*). He explicitly assumes that the Earth's size is negligible in comparison to the distance to the stars; otherwise, the Earth would not be equidistant from both poles. Ptolemy concludes, in fact, that in both cases one would never experience equinox, since the horizon would always divide the heavens into two unequal parts (Fig. 15).

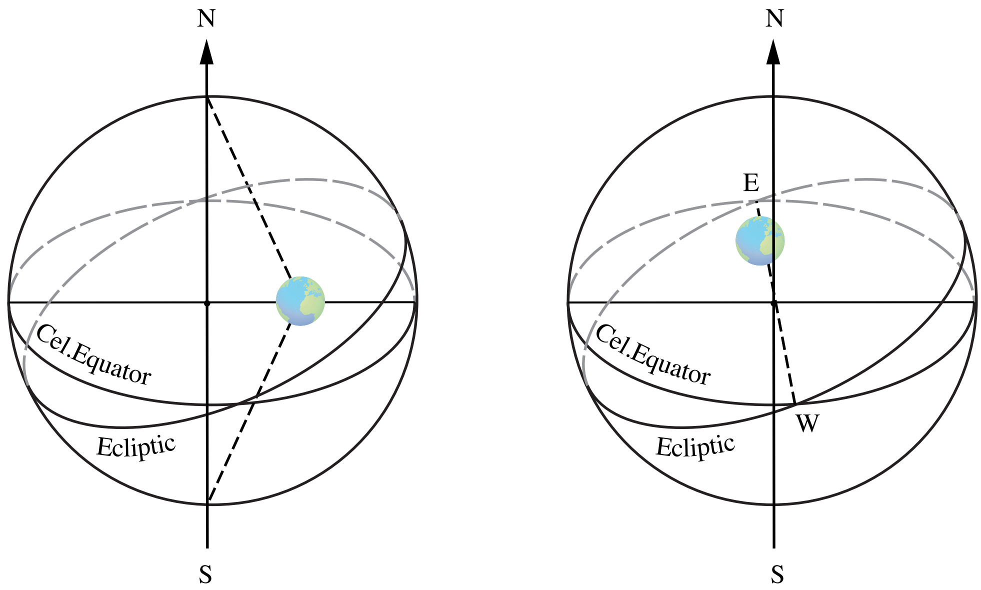


Figure 15: Two possible variants of the Earth's displacement. The Earth is equidistant from both poles and moved towards a zenith of an observer (left) or along the east-west direction (right).

Reinhold illustrates the first possible position (Fig. 15 left) with a diagram showing the cross-section of the three-dimensional model of the celestial sphere with the meridian plane at *sphaera recta* (Fig. 16).

[39] Gerald J. Toomer (ed.), *Ptolemy's Almagest* (London: Duckworth, 1983), 41.

ter à polis.

1. QVÆ phænomena repugnent, quo minus terra ſita ſit extra axem æqualiter diſtãs ab utroque polo, id eſt, in plano æquinoctialis circuli.

Cum primo ſitu hęc maxime pugnant, Nam ſi ſurſum aut deorſum terra collocata eſſet, ſequeretur hunc poſitum, quod in recta quidem ſphæra nunquam fieri poſſet æquinoctium, eo quod Horizon ſemper in duas inæquales portiones cœlum divideret, alteram ſupra terram, alteram infra.

σχόλιον.

Eſto centrum mundi A, poli eiuſdem B C, per quos deſcriptus ſit meridianus circulus B D C E. In hoc ſumatur D ſignum verticale diſtans æqualiter, hoc eſt, quadrante circuli ab utroq; polo BC, Per quod ſignum tranſeat planum æquinoctialis circuli D A E, ſecans πρὸς ὀρθὰς planum meridiani circuli. Iam ſi terra in plano quidem æquinoctialis collocata eſt, ſed extra axem mundi B C, ut in F, ſit Horizontis planum

Figure 16: Reinhold's diagram for the case of the Earth equidistant from both poles and moved towards the zenith or nadir of an observer at *sphaera recta*.

Reinhold's illustrations display the rotational axis of the universe laying horizontally, that is, they befit an observer located on the Earth's equator. To clarify his argument, we have drawn a three-dimensional representation parallel to his original schema rotated by 90°. His diagram (given in Fig. 16) can be easily understood with the help of our reworking (Fig. 17) where the observational situation at *sphaera recta* is given on the left side and Reinhold's diagram is rotated on the right.

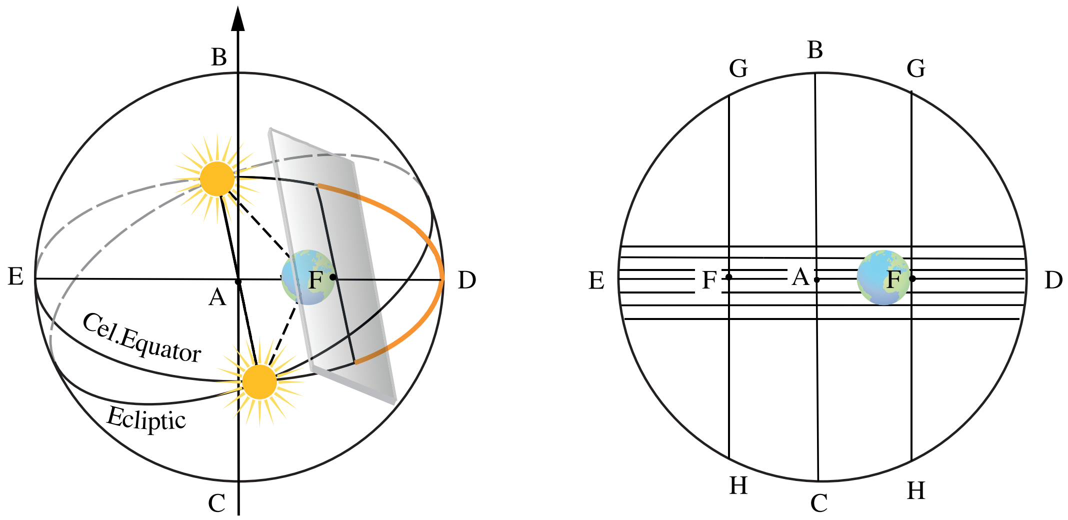


Figure 17: Observational situation at *sphaera recta* (left) and Reinhold's illustration rotated by 90° (right). The visible path of the Sun above the horizon plane (grey plane on the left) is depicted with a yellow line. Because the Earth's size is negligible in further consideration, Reinhold draws the projection of the horizon plane, line GH, at point F.

Whereas Ptolemy only considers the time of the equinox, that is, for the day when the Sun's declination is zero and the visible path of the Sun lies on the celestial equator, Reinhold tries to consider the general case in order to explain Ptolemy's short passage geometrically. In Reinhold's illustration (Fig. 17, right), A is the center of the world, B and C are the poles (that is, the line BC is the rotational axis of the cosmos), the Earth is placed at one of the points marked with F which are equidistant from both poles and lie therefore in the equatorial plane (in the picture, at the equator EAD), GFH is the cross section of the horizon plane at point F (laying at the Earth's equator) with the meridian plane going through this point. The following mathematical consideration proves that, in the case of an eccentric Earth on the equatorial plane, first, the horizon plane bisects the celestial sphere into two unequal parts and, second, (because the arcs BG and CH are equal) that the whole rotational axis of the cosmos would be displaced in parallel under the horizon plane of an observer (or above the horizon plane if the Earth is moved towards the nadir of the observer). In fact, Reinhold's geometrical illustration allows avoiding the Ptolemaic constraint to the equinoctial date and could be proved by direct observations daily.

7.2 Second example: *sphaera obliqua* for an eccentric Earth on the equatorial plane

Let us now consider the *sphaera obliqua* case for an eccentric Earth on the equatorial plane. Reinhold's corresponding illustration is marked with other letters and is not just an adaptation of the graph used for *sphaera recta* for this case, which is complicated indeed. The rotational axis is now marked with AEC where E stands for the center of the universe, the projection of the equator with BED, the tropic lines with FH and IL (Fig. 18). It is bizarre that the displaced position of the Earth along the equator is marked with the same letter F. In comparison to the first case where the position of the North Pole was not specified, here Reinhold places the North Pole ("that one which is always visible") at point A, which shows how his picture has a non-standard orientation for a modern reader since the direction west is upward and the direction east downward. As a consequence, the local horizon plane projected as a line PNFQ marks the local horizon at the southern hemisphere of the Earth.

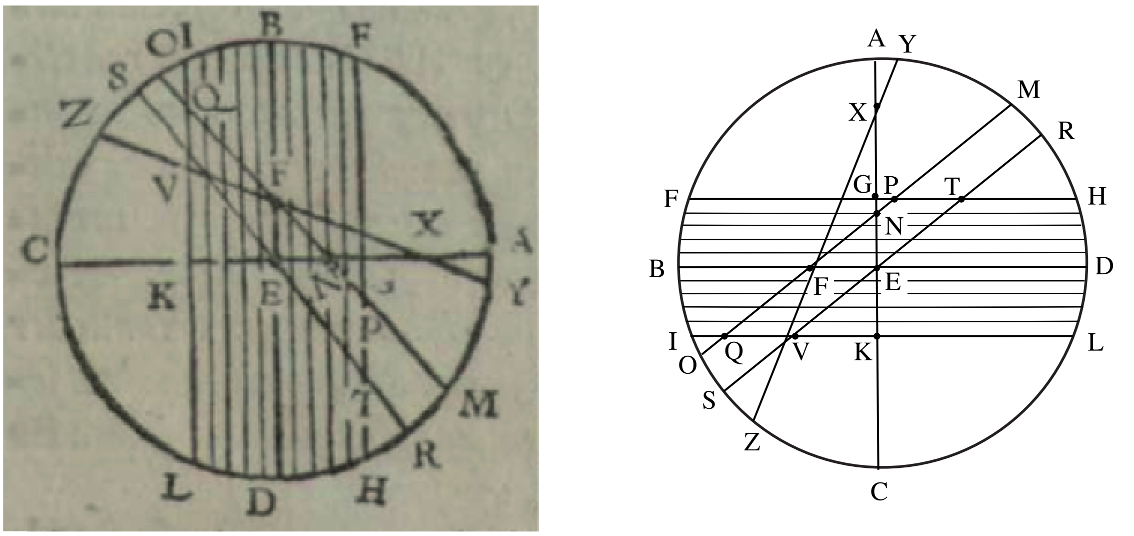


Figure 18: Reinhold's diagram for the case of the Earth equidistant from both poles and moved towards zenith or nadir of an observer at *sphaera obliqua*. Original diagram (left) and the diagram rotated by 90° (right).

Again we see that Reinhold's mathematical analysis is much more detailed than Ptolemy's. Before discussing the observational situation at *sphaera obliqua*, he notes that Ptolemy is not completely right when he writes that the horizon plane cannot cut the celestial sphere into two equal parts. By contrast, this can happen in a special case, that is to say, only “on the horizon to which one of the poles lies perpendicular“, that is, on the geographical poles of the Earth (Fig. 18). In this case, one could observe the same day-and-night duration at the true equinoctial date.[40]

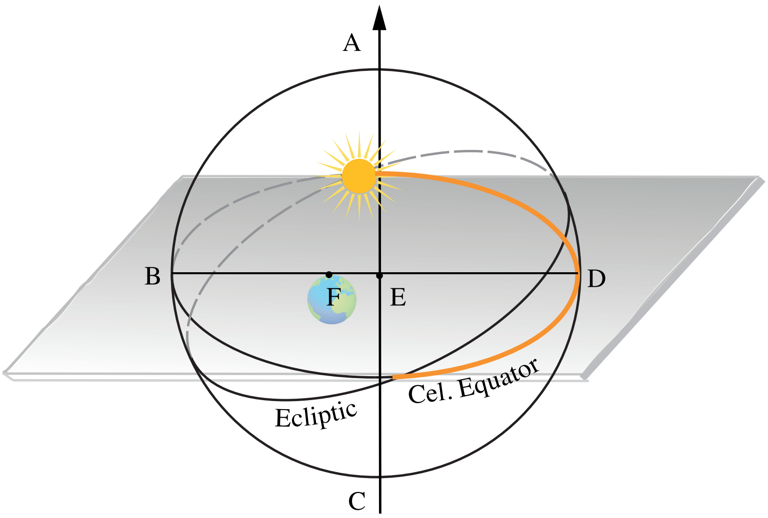


Figure 19: Observational situation at the north pole at equinox. The horizon plane parts the celestial sphere into two equal parts. Ptolemy neglected this case.

Continuing his considerations, Reinhold states that for the horizon plane YFZ (in Fig. 17) one could never observe an equinox. For the horizon plane MPO one can observe an equinox at the false date.

The case of the “false equinox” which Ptolemy only mentions incidentally is of special interest. To clarify and analyze Reinhold’s astronomical argumentation, we have isolated the lines of the diagram in Fig. 18 which are relevant for the understanding of a special case presented in his commentaries (Fig. 18, left), and provided a tridimensional interpretation (Fig. 20, right). To make a visual commentary more understandable for an observer at our latitude we have to turn to Reinhold’s diagram once more. Reinhold states that a false equinox occurs when the horizon cuts the axis AC in a point N lying below the tropic FH, thus cutting the projection of the Sun's circle at this point into halves (left). Moreover, he points out that, in the case in which a false equinox is produced, the increment of the longest day over the equinoctial day at the summer solstice (GP) will not be equal to the decrement of the shortest day from the equinoctial day at the winter solstice (KQ).

[40] Still, Reinhold does not mention that in such a situation one can still argue for geocentrism because the visible path of the Sun will span an arc on the horizon which is not equal to 180° anymore.

Such false equinox can be observed at certain latitudes on the decentered Earth only if the local horizon plane goes through the center N of the small circle of the daily visible path of the Sun (right). By contrast, if the horizon plane cuts the axis AC in some other point X lying above the tropic (Fig. 17, right), one can never have a day and night of the same duration. In the case of a "false equinox," it should be remarked that it would be impossible to discuss and to use this argument in favor of geocentrism without any visualization, that is, without the support of a diagram. Thus, the function of Reinhold's drawings is not merely explanatory since they make additional considerations possible that were not explicit in Ptolemy's text. They visually manifest the original source they comment upon and expand on its further consequences.

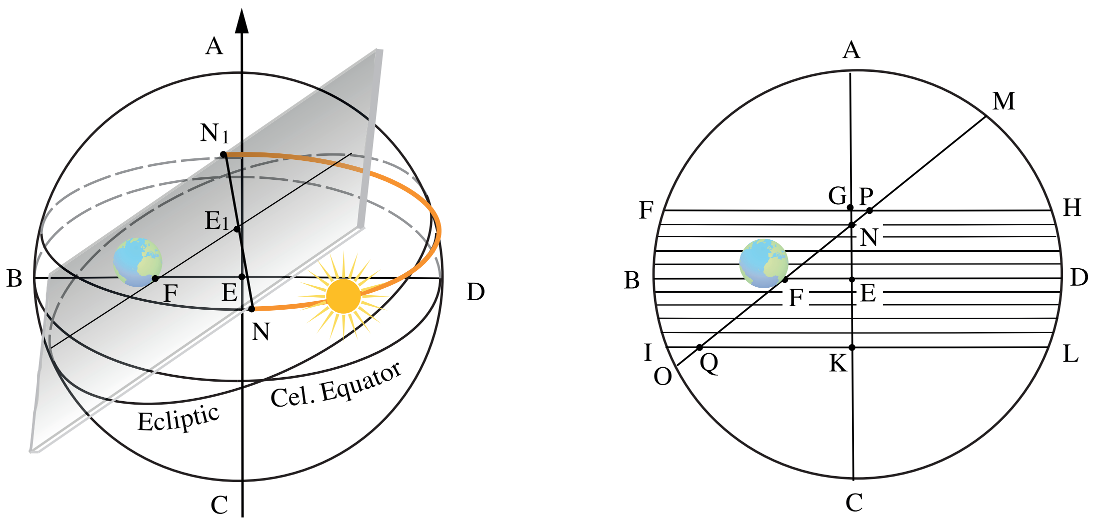


Figure 20: False equinox at *sphaera obliqua* for an eccentric Earth equidistant from both poles.

As a logical conclusion, Reinhold states that it is only in the case of the central position of the Earth in E that one can observe a true equinox, and that the increment of the longest day over the equinoctial day at the summer solstice GT will be equal to the decrement of the shortest day from the equinoctial day at the winter solstice KV.

Reinhold not only uses the diagram displayed as Figure 17 for the cases we have discussed so far. Rather, his tool is a multifunctional diagram. As Reinhold shows, it can illustrate the situation for an observer between the equator and the poles (at *sphaera obliqua*) for (i) a decentered Earth (in F) equidistant from both poles (A and C), as well as (ii) the case in which the Earth is on the world's axis removed toward one of the poles (in X or N) and also (iii) the case in which it is neither on the axis nor equidistant from both poles.

7.3 Third example: the gnomon/dioptra argument

We can now consider a third argument in favor of terrestrial centrality refuting the hypothetical case of a displacement of the Earth along the north-south directions based on the observations of the gnomon's shadow at equinoxes (*Almagest* I H19):

> [...] if the Earth were not situated exactly below the [celestial] equator, but were removed towards the north or south in the direction of one of the poles, the result would be that at the equinoxes the shadow of the gnomon at sunrise would no longer form a straight line with its shadow at sunset in a plane parallel to the horizon, not even sensibly.[41]

Reinhold's commentary to this argument is endowed with a simple graph (Fig. 21), which he could derive from earlier commentaries such as Theon's.

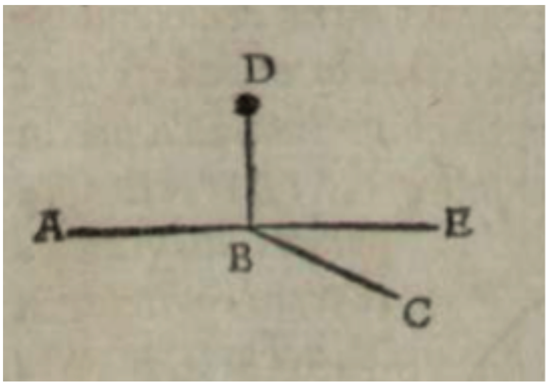


Figure 21: Reinhold's illustration for the observation with gnomon.

In this graph (Fig. 21), the lines AB, BC and BE lie in the plane of a horizon and a gnomon BD is mounted perpendicular to this plane. At equinox, the Sun rises at point A and the shadow of the gnomon lies along BE, at sunset at point E, to the contrary, the shadow lies along BA. Reinhold remarks that, according to long-time

[41] Toomer (ed.) *Almagest*, 42.

observations, two lines, AB and BE are on the same straight line. The shadow marked by the line BE does not move under some angle to EA (e.g. the line BC).

For the sake of clarity we would like to remark that this argumentation only proves that an observer is located at the intersection of two great circles of the celestial sphere (Fig. 22), the celestial equator and the ecliptic. It is an old argument that can be found in many sources including Pliny's *Natural History* (I 70) and can be traced back to Euclid (*Phenomena,* I).[42]

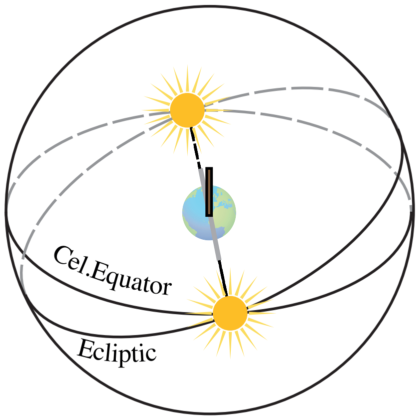


Figure 22: Geocentric argument with the observation with gnomon. At equinox, the shadows of a gnomon at sunrise and sunset lie at the same line; therefore, the gnomon is located at the intersection of two great circles.

7.4 Fourth example: argument from terrestrial size

An additional geocentric argument of Ptolemy's concerns the horizon planes:

> Another clear indication that this is so [the Earth is in the middle] is that the planes drawn through the observer's lines of sight at any point [on Earth], which we call 'horizons', always bisect the whole heavenly sphere. This would not happen if the Earth were of perceptible size in relation to the distance of the heavenly bodies; in that case only the plane drawn through the center of the Earth could bisect the sphere, while a plane through any point on the surface of the Earth would always make the section [of the heavens] below the Earth greater than the section above it.

[42] Cf. Omodeo and Tupikova, "Cosmology and Epistemology" (2016).

Reinhold illustrates this argument schematically (Fig. 23).

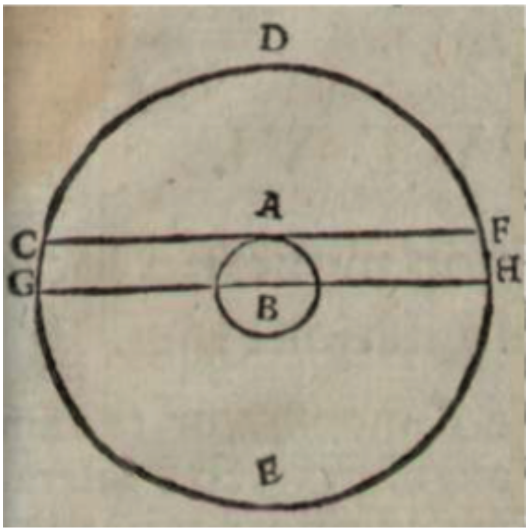


Figure 23: Reinhold's diagram illustrating Ptolemy's argument on the size of the Earth.

His diagram was possibly derived from Theon's 1538 edition (as reproduced in Fig. 13). In this case, as in the former, the visualization is important to quickly understand the argument but no innovative graphic representation is necessary (as was the case with the multifunctional diagram discussed in relation to the first two arguments). In the above diagram the letter A indicates the point on the Earth's surface and CAF is the plane of the horizon, the parallel plane GBH goes through the center of the Earth. Reinhold claims that if the Earth would have a perceptible size relative to the distance to stars, the arc CDF would be always bigger than the arc FEC because only the hemispheres CDF and FEH are of the same size. Because we cannot notice the difference between two arcs, CDF and GDH, (that is, to measure the equal arcs CG and FH), the diameter of the Earth (equal to a chord which should span a double of the arc CG) is also negligible.

8. The Reception of Reinhold's Visual Commentaries

Reinhold's commentaries were the printed continuation of a handwritten culture that was still alive in his time. In fact, authoritative annotations were copied and transmitted in the margins of the printed books. This is a cultural habit that has been pointed out in the history of Renaissance astronomy by Owen Gingerich. In his valuable census of the first two editions of Copernicus's major work he grouped copies according to their marginalia as well as other factors. In particular, some of Reinhold's manuscript glosses, comments and corrections to *De revolutionibus* were transcribed and were widely circulated by his pupils and followers.[43] Among his pupils, epicyclical devices serving as substitutes for the Ptolemaic equant constituted one of the aspects of Copernicus's geometrical models that were well received.[44] They had the advantage of respecting the so-called "astronomical axiom", according to which heavenly motions are either circular and uniform about their centers or they result from the composition of uniform motions. Reinhold's diligent annotations are inserted throughout his own copy of *De revolutionibus* except for the part of the first book dealing with cosmological and natural views. They were copied and circulated by his pupils and followers.[45]

There is additional evidence that his graphic commentaries on Ptolemy also resonated with others and were circulated in the form of manuscript marginalia in copies of the *Almagest*. Our evidence is a copy of the 1528 edition of the *Almagest* that belonged to two reputable Renaissance professors of mathematics and medicine, namely the Fleming Heinrich Brucaeus (1530-1593) and the Scott Duncan Liddel (1561-1613). The former, who was professor at Rostock from 1567 onwards and court physician of Mecklenburg, taught mathematics to illustrious scholars, among them Liddel and the Danish astronomer Tycho Brahe (1546-1601), with whom he was in continuous correspondence. Duncan Liddel studied and taught mathematics and medicine at Frankfurt (Oder), Rostock, Helmstedt in Germany and at Aberdeen in Scotland.[46] The University Library of Aberdeen preserves his and Brucaeus's copy of the *Almagest*. The first book is heavily annotated (Fig. 24).

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[43] Owen Gingerich, *An Annotated Census of Copernicus' De Revolutionibus (Nuremberg, 1543 and Basel, 1566)* (Leiden-Boston: Brill 2002). Also see idem, *The Book Nobody Read: Chasing the Revolutions of Nicolaus Copernicus* (New York: Walker & Company, 2004).

[44] Ptolemy's equant refers to a mechanism accounting for the variation of linear speed in planetary motions. In the mathematical modeling of planetary motions, the center of the epicycle (a circlet deputed to transport the celestial body) is centered on a rotating deferent (the main transporting circle, eccentric with respect to the cosmological center); an equant point is posited along the line connecting the cosmological center to the eccentric center of the deferent; the center of the epicycle is supposed to move with constant angular speed relative to the equant producing a variation in linear speed. This variation was seen as a disadvantage by supporters of celestial uniformity of circular motion, e.g. by Copernicus and Reinhold.

[45] See Kremer, "Kepler", 2009.

[46] Pietro D. Omodeo, "Sixteenth Century Professors of mathematics at the German University of Helmstedt: A Case Study on Renaissance Scholarly Work and Networks," *Preprints of the Max Planck institute for the History of Science* 417 (2011); Pietro D. Omodeo and Karin Friedrich, eds. *Duncan*

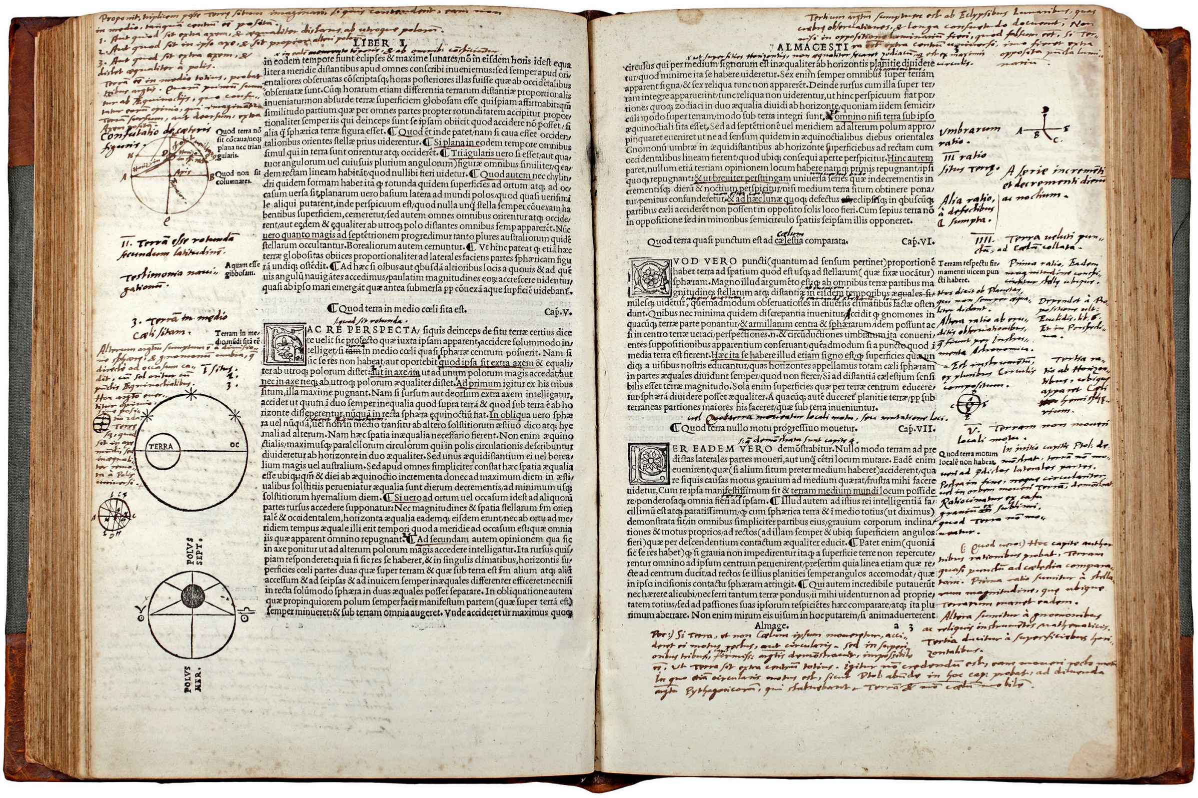

Figure 15: Brucaeus's and Liddel's Copy of the *Almagest* (Venice, 1528) with manuscript annotations from Reinhold's commented edition of the *Almagest*, Book 1.

Upon close examination one can notice that diagrams and explanations are taken from Reinhold's edition (Fig. 25 and Fig. 26). As we already remarked, the Venetian editions of the *Almagest* lacked explanatory illustrations, which are a presupposition for a precise understanding of the astronomical text and its further implications. Therefore these marginalia integrate Ptolemy's theses with important information. The fact that a manuscript circulation of these marginalia accompanied printed editions shows that medieval practices of manuscript commentary were still in use even in the late Renaissance. It is evident that they were not perceived as separate from the circulation of knowledge through printed sources.

Liddel (1561-1613): Networks of Polymathy and the Northern European Renaissance (Leiden-Boston: Brill, 2016).

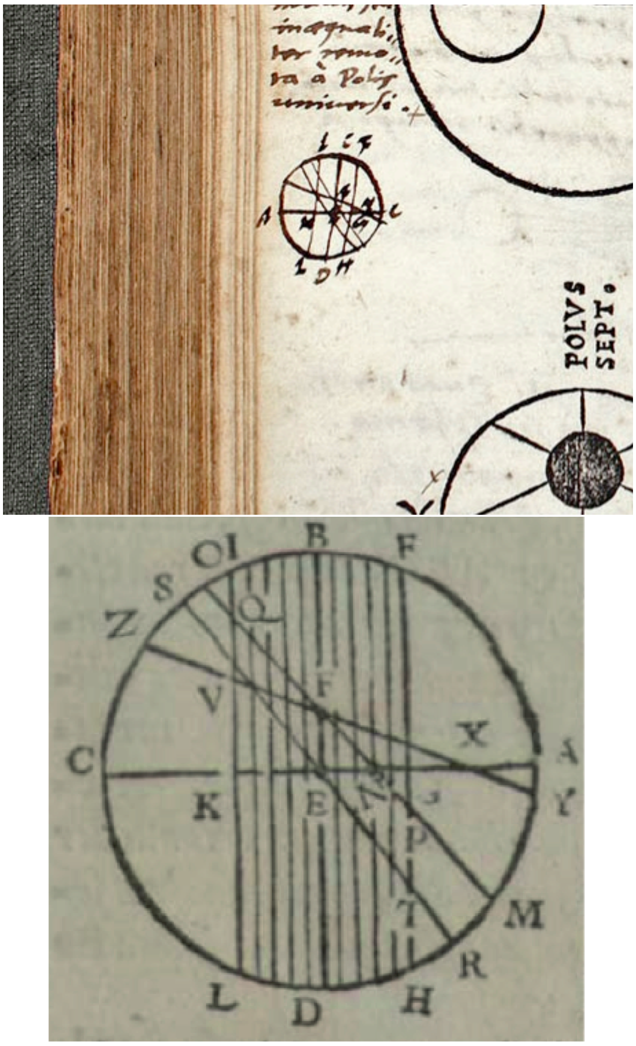

Figure 25: Detail from Brucaeus's and Liddel's copy of the *Almagest* showing a transcription of Reinhold's multifunctional diagram.

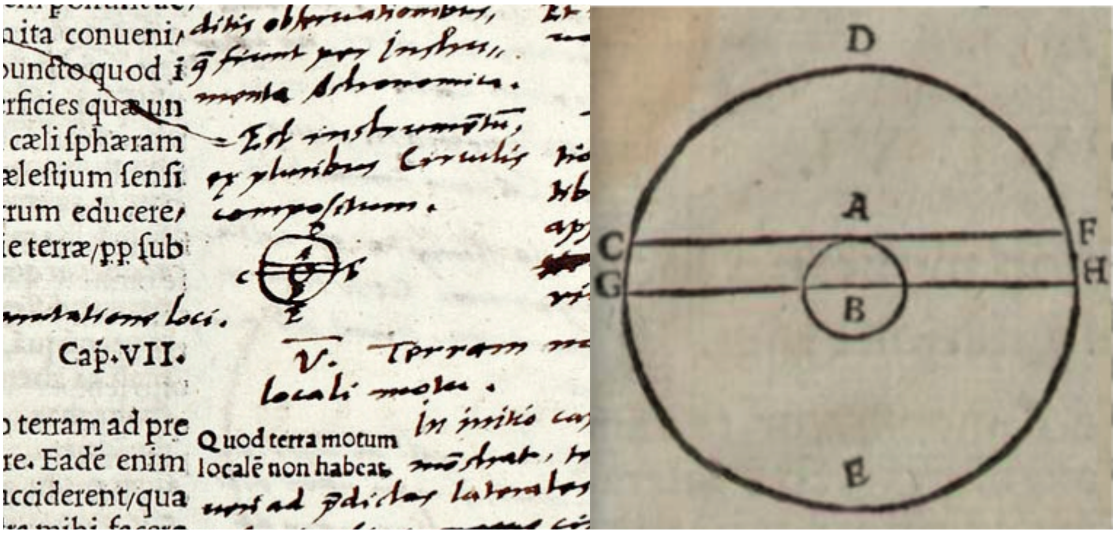

Figure 26: Detail. A manuscript copy of Reinhold's diagram, illustrating Ptolemy's argument on the size of the Earth.

9. Concluding Remarks

In this essay we considered several examples of Renaissance astronomical commentaries in which mathematics and particularly geometry played an important explanatory role. Unlike other disciplinary fields, diagrams and geometrical representations constitute a specific visual tool for the correct understanding of the sources in mathematical astronomy (then and now). In the context of reformed Wittenberg, the acknowledgment of the pedagogical relevance of the humane letters and mathematics forged a generation of brilliant mathematicians such as Copernicus's pupil Georg Joachim Rheticus and Erasmus Reinhold. Both, but especially Reinhold, were close collaborators of Philipp Melanchthon. Reinhold certainly fostered his mentor's educational program. In this context, mathematics was put at the service of philology for the interpretation of sources such as Pliny's *Natural History*, a standard teaching text. It was the task of mathematicians like Johannes Milich and Reinhold to prepare commented editions of the second book, which dealt with astronomical issues, to the advantage of students. As it seems from documental evidence, Reinhold especially contributed to the understanding of Pliny's passages on planetary motions by drawing diagrams to be included in widespread German editions.

Collaborative work marked the scholarly activity of the Wittenberg group gathered around Melanchthon. While Reinhold exchanged drawings and ideas with Milich, Melenchthon prepared an introduction to physics together with the professor of natural philosophy Paul Eber. In this introduction the Copernican planetary theory was discussed and rejected. Reinhold advised Melanchthon on mathematical-astronomical issues and prepared a commentary on the general part of Ptolemy's *Almagest* (book one of the Hellenistic classic) that was printed in 1549, the same year as Melanchthon's introduction to physics. Textbooks and commentaries were issued together as part of a collective scholarly endeavor.

What is particular in Reinhold's commentaries is the centrality of geometrical explanation and representation. As a matter of fact, he prepared a Greek-and-Latin edition of the first book of the *Almagest* that was accessible to students. It was endowed with old and new diagrams that made geometrical arguments in favor of geocentrism easily comprehensible. Some of them show a striking originality and reached a degree of abstraction that permitted Reinhold to consider the consequences of a hypothetical displacement of the Earth in better detail than in Ptolemy's treatment. In the late humanistic context of Wittenberg, mathematical skills reinforced philology and vice versa. The renewed study of Ptolemy could offer answers to new theoretical challenges such as those raised by Copernicus, of whom Wittenberg was one of the first centers of reception, albeit critical.

It should be further remarked that there was no clear-cut divide between the medieval commentary tradition and the modern editorial culture in the Gutenberg era. We would like to emphasize continuity rather than opposition. The publication of commented editions of classical sources represents a continuation of earlier intellectual practices through new means. Typography actually empowered cultural and teaching practices inherited from the Middle Ages. Among the benefits of the Gutenberg technology, commentaries could be re-issued in rapid succession offering the opportunity to improve on them. This is substantiated by our comparison between Jakob Ziegler's first printed commentary to the second book of Pliny in 1531 and those by Milich. Milich's rough diagrams in the commentary of 1535 were soon substituted by more refined ones, possibly drawn by Reinhold. Moreover, erudite Renaissance commentators did not limit themselves to ancient sources. Rather, they applied well-tested methods of appropriation and transmission to the "new classics". Reinhold exercised his wit as a commentator on ancient sources such as Ptolemy and Pliny as well as on modern authors, such as Peuerbach and Copernicus.

It was not only written and oral commentary practices that influenced the editorial culture of the Renaissance. The habit of enriching texts with handwritten commentaries lasted a long time. Authoritative glosses could be inserted and copied in printed books just as they were inserted in the codices of the past. For instance, poorly illustrated printed editions of Ptolemy could be integrated with explanatory diagrams taken from Reinhold. The manuscript circulation of diagrams as glosses is corroborated by the marginal notes added by the Rostock professor Heinrich Brucaeus to a 1528 Venetian edition of the *Almagest* that was later brought to Scotland by the polymath Duncan Liddel. Manuscript commentaries circulated during the Renaissance together with people, libraries and ideas. The scholars of the time of the press did not renounce the transfer dynamics secured by the commentary culture but rather accelerated them with more powerful technological means.

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