Chapter 2
The Illustrated Printed Page as a Tool for Thinking and for Transmitting Knowledge. The Case of the *Theoricae Planetarum*

Isabelle Pantin

Abstract During the early modern period, astronomy underwent a profound transformation in the way it was taught, as the response of an enlarged readership took on more and more importance. This change notably concerned the use of images and diagrams. The *Theoricae planetarum*, especially Peuerbach's *Theoricae novae planetarum*, are a privileged example in this respect, for they served a particularly large range of functions. They were mnemonic tools and visual glossaries, and an essential element in Peuerbach's pedagogical approach. They had a documentary role, as they gave plausible representations of the celestial spheres; they could be used as proofs of the soundness of a "theory," or could simply help to follow a geometrical demonstration. Some of them were small-scale models designed to serve as tools for the mind to better grasp the complex combination of movements in what was then called *machina mundi*. All these figures, and their power to exercise the mind, were well suited to a period when more and more astronomers were involved in imagining, drawing, and comparing hypothetical models of planetary movements.

Keywords *Theoricae planetarum* · Georg von Peuerbach · Knowledge transmission · Movements · Demonstration

2.1 Introduction

During the early modern period, astronomy underwent a profound transformation, not only in its methods, its aims, and its theoretical developments and prospects, but also in the way it was taught and even popularized as the response of an enlarged readership to the works of astronomers took more and more importance. All these changes were mirrored in (and sometimes accelerated by) the evolution of the layout of the books, notably concerning their use of images and geometrical diagrams.

I. Pantin (✉)
École Normale Supérieure (Paris)-PSL, IHMC (UMR 8066), Paris, France
e-mail: isabelle.pantin@ens.fr

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I shall examine this evolution in a particular kind of astronomical book, the *Theoricae planetarum*, which gave images a role both prominent and multiple. In the *Theoricae*, especially in the *Theoricae novae planetarum*, written by Georg von Peuerbach (1423–1461) in the middle of the fifteenth century, the diagrams, in association with the text, were conceived as tools primarily for teaching a difficult mathematical discipline, but secondarily for helping the reader to understand that this discipline, astronomy, had various levels.

The first level was purely technical, as astronomy's main task was to calculate and predict the positions of the stars by conceiving geometrical models of celestial movement. But, on the other hand, astronomy was linked to philosophy in the sense that it was concerned with the organization of the cosmos. This is an old problem, posed by Pierre Duhem in terms of a perennial opposition between "instrumentalism" and "realism" (Duhem 1969). However, the contrast between these positions becomes blurred when the issue is approached through images and representations.

I shall thus try to place the diagrams of the *Theoricae* in their context, and to analyze their functions, while addressing the wider issue of the relationship between the subject of the treatise they belonged to (the science of planetary motions) and the extensive use of visual expression.

2.2 From the *Theorica Vetus* to Peuerbach's *Theoricae Novae*

If we go back to their probable origins, the *Theoricae* were a byproduct of higher astronomical theory, whose model was the *Almagest* of Ptolemy (ca. 100–ca. 170). They were meant to reduce the geometrical analysis of planetary motions—with its complete demonstrative apparatus—to pedagogical expositions that described models of kinematic motion in nearly the same manner that the construction of certain astronomical instruments can be described. This purpose was already present in Ptolemy's *Planetary hypotheses* (Goldstein 1967; Hartner 1968; Murschel 1995; Evans 2003; Hamm 2016). Although the treatise was not directly available to Latin-speaking astronomers,[1] it was translated into Arabic (and from Arabic into Hebrew). A tradition originated from it, whose paths of transmission are somewhat opaque. A crucial role was probably played by the twelfth-century translations of the *Elements of astronomy* of al-Farghānī (Alfraganus, ninth century) by Johannes Hispalensis (fl. 1118–1142) and Gerardus Cremonensis (ca. 1114–1187), and by the anonymous Spanish and Latin translations of the treatise *On the configuration of the world* of Ibn al-Haytham (Alhazen, 965–1040) in the thirteenth century (Langermann 1990; Mancha 1990; Samsó 1990; Hugonnard-Roche 1996; Sylla 2017). At any rate, from the second half of the thirteenth century the explanation of planetary motion through

[1] Only the first part of the first book of the *Planetary hypotheses* has survived in the original Greek text (in only two manuscripts); it was printed for the first time in 1620, with a Latin translation (Bainbridge 1620).

the description of geometrical models constituted the upper level of astronomical teaching at the university. It was known as *Theorica planetarum* (Pedersen 1962, 1975).

The most widely diffused *Theorica* was the *Theorica communis* (or *Theorica vetus* or *Theorica Gerardi*, as it was falsely attributed to Gerardus Cremonensis in some fourteenth- and fifteenth-century manuscripts and in the incunabula editions).[2]

Theorica communis probably owed its success to its relative simplicity; its main challenger, the *Theorica* of Campanus de Novara (1220–1296) was more complex and required higher technical and mathematical skills to penetrate (Benjamin and Toomer 1971). The *Theorica Gerardi*, which survives in more than 210 manuscripts (Pedersen 1981), follows a straightforward plan. It defines the principal astronomical terms; it describes the circles and lines of the Sun, the Moon (the explanation of the motion of the nodes included),[3] the superior planets (Mars, Jupiter, and Saturn), Venus, and Mercury; and it gives some instructions for computing these motions with the aid of astronomical tables.

In the Renaissance, the *Theorica communis* was totally supplanted by the *Theoricae novae* of Georg Peuerbach—originally a course taught in 1454 at the *Collegium civium* in Vienna. Peuerbach's more brilliant disciple, Johannes Regiomontanus (1436–1476), copied his master's manuscript, richly illustrated with twenty-nine large diagrams;[4] some twenty years later, between 1472 and 1474, he printed the work in Nuremberg[5] with thirty diagrams that faithfully reproduced (though with some slight improvements) those of the original manuscript.[6]

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[2] Some Renaissance scholars, like Bernardino Baldi, preferred an attribution to Gerardus de Sabbionetta, a thirteenth-century astrologer (Baldi 1707, 91). Both attributions are based on little evidence, and even the date of the treatise is under discussion (Pedersen 1981; Federici-Vescovini 1996, 1998). The text is best identified by its *incipit* (a definition of the eccentric circle): "Circulus ecentricus vel egresse cuspidis vel egredientis centri dicitur [*or* "est"] qui non habet centrum suum cum centro mundi." See also (Gerardus 1942).

[3] The lunar nodes are the two opposite (and moving) points at which the eccentric circle of the Moon (that bears the epicycle with the Moon's body) intersects the path of the Sun (that is the ecliptic). One is the ascending node, or dragon's head (*caput draconis*), where the Moon "begins to turn to the north;" the other is the descending node, or dragon's tail (*cauda draconis*), where the Moon turns to the south (Gerardus 1974, §29–31). When the Moon is at a node, and either full or new, an eclipse may occur.

[4] Regiomontanus' autograph copy is now in Vienna (ÖNB, *Palatinus Latinus* 5203, 1r–26v). See (Peuerbach 1454; Grössing 1983, 101–102; Zinner 1990, 203; Malpangotto 2012, 344–346).

[5] In Regiomontanus' edition the last section, *De motu octavae sphaerae*, is more complete than in the early manuscripts, copied around 1454; we know that the addition was written by Peuerbach shortly before his death, for the manuscript of the *Theoricae novae* he bequeathed to Bessarion in April 1461 (now in Rimini, Biblioteca civica) contains it. In this manuscript, the last two leaves are now missing, but what remains of the *De motu octavae sphaerae* in this last redaction corresponds exactly (notwithstanding insignificant variants) to the text in the *editio princeps* (Peuerbach 1461; Malpangotto, 2012, 379–380).

[6] The only diagram whose model is not in the known early manuscripts of the *Theoricae novae* concerns the eighth sphere and was probably drawn in the missing leaves of the Rimini manuscript.

Regiomontanus soon began a defamatory campaign against the *Theorica vetus* in order to impose his master's *Theoricae novae* as the only legitimate and reliable introduction to the knowledge of planetary motions. In 1476, he printed a dialogue that criticized many errors of "Gerardus" (Pedersen 1978; Shank 2012), later republished under the revealing title *Disputationes contra Cremonensia in planetarum theoricas deliramenta* (*Disputations against Gerardus Cremonensis' delirious ravings*).[7] Regiomontanus' purpose was not only to point out the old textbook's mistakes, some of which, by the way, had already been discussed and corrected by medieval commentators (Byrne 2011), but also to launch an attack against the traditional astronomy of eccentrics and epicycles, as, according to Shank (2012), the *Disputationes* are much indebted to Henry of Langenstein's *De reprobatione ecentricorum et epiciclorum* (1364) (Kren 1968). Regiomontanus probably carried copies of this pamphlet and of the *Theoricae novae* when he left Nuremberg for Venice, then Rome, where he was to die in July 1476.

At that time, the *Theorica Gerardi* had been printed twice in Venice and in Ferrara (Gerardus 1472a, b), together with the *Sphaera* of Johannes de Sacrobosco (died ca. 1256). Campanus' *Theorica* was never printed. Three subsequent editions, still paired with editions of the *Sphaera*, appeared in 1478 and 1480 (Gerardus 1478a, b, 1480), after which the *Theorica Gerardi* was no longer regarded as the standard textbook on the subject. The Venetian printers printed the *Theoricae novae* instead, introduced by Regiomontanus' attack on "Gerardus' delirious ravings."

The *Theorica Gerardi* was henceforth no longer of interest except as a document on medieval astronomy. In 1518, the Venetian bookseller Luca Antonio Giunta (1457–1538) published a large astronomical anthology, prepared by a Roman physician, Girolamo de Nuciarelli (fifteenth–sixteenth century), which was also published—probably some months afterward—by the heirs of Ottaviano Scoto (died ca. 1499) (Nuciarelli 1518, 1518/1519).[8] The main difference between the collections is that Giunta had the *Theorica Gerardi* appended to the beginning. This addition was mentioned and justified on the title page: "The *Theory of planets* of John [*sic*] of Cremona, most useful for [reading] Regiomontanus' *Disputationes*, that you cannot find in the other printed editions" (*Theorica planetarum Joannis [sic] Cremonensis plurimum faciens ad disputationem Joannis de Monte Regio, quam in aliis impressis non reperies*). The next collection, prepared by Luca Gaurico (1475–1558), still contained the *Theorica Gerardi*, but it was never printed again in the sixteenth century (Gaurico 1531).

[7] In the Nuremberg first edition, the dialogue *Disputationes contra Cremonensia in planetarum theoricas deliramenta* is untitled.

[8] The Scoto edition is dated January 19, 1518, the Giunta edition June 30, 1518. As these dates are probably expressed in "Venetian style" (*stile veneto*, *mos venetus*) with the beginning of the year fixed on the first of March (Cappelli 1983, 16), the Scoto edition must have appeared in January 1519, and Giunta was the first publisher of the collection. The addition of the old *Theorica* was probably determined at the last moment: the text is printed in the first quire (A3v–A6r), which was almost always printed last, and it is mentioned at the end of the list on the title page.

2.3 The Role of Illustration in the Rivalry Between the Old and New *Theories*

This complete victory of the new over the old treatise was certainly encouraged by the attack of Regiomontanus, launched at the very beginning of the printed career of the *Theorica planetarum*, when only a handful of printers (in northern Italy) published this kind of textbook. However, the decisive factor was likely that the intrinsic qualities of Peuerbach's treatise were imposed upon the viewer by the concerted use of images.

To begin with, the *Theoricae novae* are much more complete than the old *Theorica*. They are also more clearly written and organized, and every element of their descriptions is developed in a distinct subsection illustrated by a large diagram with a title (Fig. 2.1).

Each "chapter" on a particular planet (or group of planets in the case of the three "superior planets"[9] and Venus[10] that share the same diagrams) is illustrated with a series of specialized diagrams, always in the same order: first a global figure, discussed further below (*Theorica Solis* or *Theorica Lunae*, and so on) (Fig. 2.1), then a diagram of the axis and poles of the circles on which depend the planet's movements (*Theorica axium et polorum*) (Fig. 2.2), that of the different lines used for determining the planet's position and movement (*Theorica linearum et motuum*), and, if necessary, that of the "proportional minutes,"[11] which is necessary data for the calculations. In comparison, the old *Theoric*a had, at best, one diagram to accompany the entire analysis.

The scope of the new treatise was also wider. Whereas the *Theorica vetus* was purely geometrical, the *Theoricae novae* more completely fulfilled the original purpose of Ptolemy's *Planetary hypotheses*: to construct virtually three-dimensional

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[9] The three planets above the Sun, in the Ptolemaic system, Mars, Jupiter and Saturn, were traditionally dealt with together, for the mechanisms of their movements were similar.

[10] The *Theoricae novae* clearly link the superior planets with Venus, as the corresponding diagram is entitled "Theorica trium superiorum et Veneris," though the chapter "De tribus superioribus" is followed by the very short "De Venere," ending with these words: "the definitions of terms are here throughout just as for the superior planets" (Peuerbach 1987, 22). By contrast, the *Theorica Gerardi* has a section on the superior planets ("Sequitur de tribus planetis") followed by a section on Venus and Mercury ("Sequitur de Mercurio et Venere"), which, in fact, mainly deals with the complicated movement of Mercury, except in one passage that refers, for a series of definitions and descriptions, to the section on the superior planets ("Medius vero motus Mercurii et Veneris…omnia ista sic describuntur in Mercurio et Venere, sicut in tribus superioribus"). Then, at the end of the section, the similarity between Venus and the superior planets is stated: "Venus vero habet deferentem et aequantem dispositos sic sicut tres superiores…Omnia alia de Venere similia sunt in tribus superioribus."

[11] The "proportional minutes" ("minuta proportionalia") refer to the division into sixty parts, or minutes, of the distance between the apogee and the perigee of the eccentric deferent of the planet. This division plays a role in the calculation of the motions of all the planets with epicycles. The Moon, the superior planets, and Mercury each have a specific mode of calculation and a specific corresponding diagram. In the first incunabula editions of the *Theoricae novae*, hand coloring was used to improve the clarity of these diagrams.

Fig. 2.1 The orbs of Mercury. Munich, Bayerische Staatsbibliothek. Ink P-399, urn:nbn:de:bvb:12-bsb00030432-6. From (Peuerbach ca. 1473, 9r)

models of the planetary orbs, in order to demonstrate that the sophisticated geometry of eccentrics and epicycles—which, in the *Almagest*, accounts for the celestial motions—was both mechanically plausible (and potentially reproducible in actual instruments) and compatible with the Aristotelian cosmos composed of concentric celestial orbs (Lerner 1996, 74–81; Evans and Carman 2014; Hamm 2016). According to Peuerbach's nearly three-dimensional models, the "total orb" of each planet, itself perfectly concentric with the sphere of the universe, was divided into partial contiguous orbs, responsible for every component of the planet's complex movement. Some of these partial orbs were "deformed" (i.e., with one surface

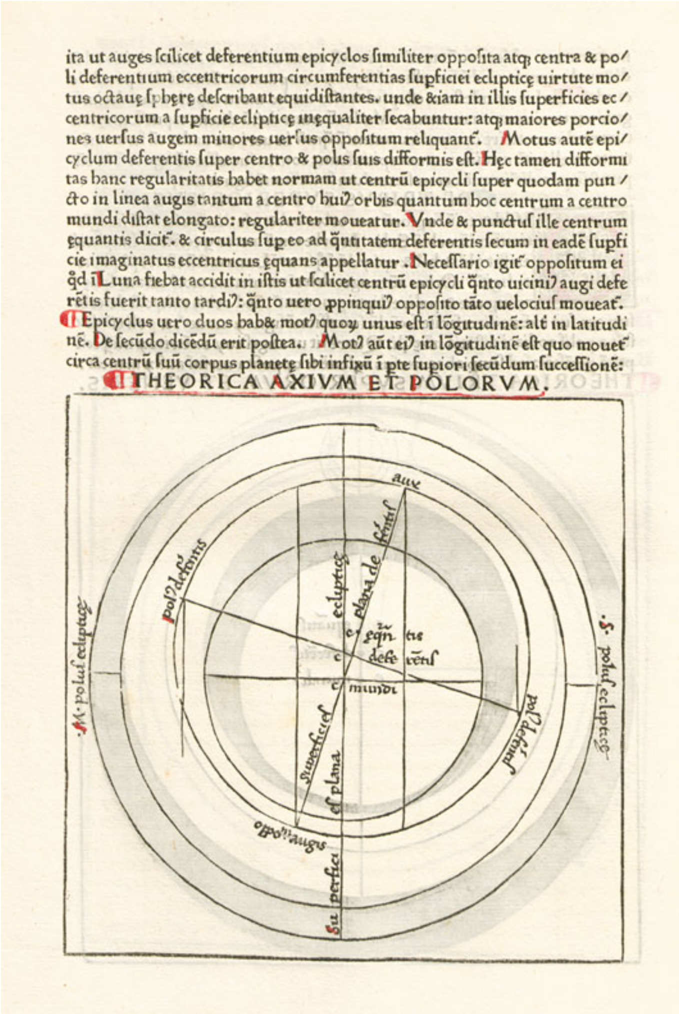
ita ut auges scilicet deferentium epicyclos similiter opposita atq; centra & po/
li deferentium eccentricorum circumferentias supficiei eclipticę uirtute mo/
tus octauę sphęrę describant equidistantes. unde &iam in illis superficies ec/
centricorum a supficie eclipticę inęqualiter secabuntur: atq; maiores porcio/
nes uersus augem minores uersus oppositum relinquant. Motus autē epi/
cyclum deferentis super centro & polis suis difformis est. Hęc tamen difformi
tas hanc regularitatis habet normam ut centrū epicycli super quodam pun/
cto in linea augis tantum a centro hui9 orbis quantum hoc centrum a centro
mundi distat elongato: regulariter moueatur. Vnde & punctus ille centrum
ęquantis dicit. & circulus sup eo ad q̄ntitatem deferentis secum in eadē supfi
cie imaginatus eccentricus ęquans appellatur. Necessario igit oppositum ei
q̄d i Luna fiebat accidit in istis ut scilicet centrū epicycli q̄nto uicini9 augi defe
rētis fuerit tanto tardi9: q̄nto uero ꝓpinqui9 opposito tāto uelocius moueat.
Epicyclus uero duos hab& mot9 quoꝝ unus est ī lōgitudine: alt in latitudi
nē. De secūdo dicēdū erit postea. Mot9 aūt ei9 in lōgitudinē est quo mouet
circa centrū suū corpus planetę sibi infixū ī pte supiori secūdum successionē:
THEORICA AXIVM ET POLORVM.

Fig. 2.2 The axes and poles of the superior planets. Munich, Bayerische Staatsbibliothek. Ink P-399, urn:nbn:de:bvb:12-bsb00030432-6. From (Peuerbach ca. 1473, 6v)

concentric with the universe and one surface eccentric); others were completely eccentric (Aiton 1981; Lerner 1996, 115–126).

This was even highlighted by the illustration. In the first incunabula editions, the diagram that, at the beginning of each "chapter" on a particular planet, shows the general arrangement of its total and partial orbs, is hand colored, with some of the partial orbs painted green or blackened with ink, to increase legibility and the realism of the representation, and perhaps to suggest three-dimensionality (Fig. 2.1).[12] This was not an absolute innovation; in a few manuscripts of the *Theorica Gerardi*, color or ink blackening was used to clarify certain diagrams and to highlight that the orb which contains the planet and its epicycle (the "deferent" orb) is inserted between partial orbs.[13] But in the manuscripts of the old *Theorica* the function of the unique diagram that represents one planet (or group of planets), color or no color, is to show the geometrical lines and circles that account for the movement of the planet in question. This diagram corresponds mainly to the type of diagrams called *Theorica linearum et motuum* in the *Theoricae novae*. Whereas in the *Theoricae novae* the diagrams with parts blackened or colored in green are devoted only to showing the arrangement of the orbs. Thus, the effect is much more striking.

The diagrams of the *Theoricae novae* were certainly unusual and eye-catching, but they were linked to a tradition. The importance given to the illustration was a fundamental generic feature of the *Theories of planets*. Many manuscripts of the *Theorica Gerardi* were illustrated with a set, more or less complete, of five diagrams (Müller 2008, 253–266), sometimes with one or two additions. The five diagrams, as already mentioned, show lines and circles corresponding to the geometrical analysis of the movements of the planets: one diagram for the Sun, two for the Moon (one for the object itself, the other for the nodes of the Dragon), one for the superior planets, and one for Venus and Mercury.[14] An additional diagram often illustrates the causes of the stations and retrogradations of the planets.[15]

In the first 1472 editions of the *Theorica Gerardi*, there were large blank spaces that make room for hand-drawn figures, but no diagrams (Gerardus 1472a, b).[16] The 1478 edition, printed by Franz Renner (fl. 1471–1486) was illustrated with eight diagrams (Gerardus 1478a; Sander 1942, n° 6659), which were copied in the next 1478 and 1480 editions (Gerardus 1478b, 1480; Sander 1942, no. 3085, 6660). In the meantime, Peuerbach's *Theoricae novae* had been printed in Nuremberg with their thirty striking figures and circulated in Italy, and Renner's diagrams, which undoubtedly belong to the tradition of the old *Theorica*'s illustration, were marginally influenced by the diagrams of the new treatise.

In the four diagrams of the movements of the planets (Sun, Moon, superior planets, and Mercury) ink blackening makes visible the partial "deformed" orbs surrounding the eccentric orb (Gerardus 1478a, b, e2r, e4r, e9r, e10v). But this is not necessarily

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[12] See, for instance, one of the copies of the *Theorica planetarum* in Munich, Bayerische Staats-Bibliothek (BSB Clm 27), digitized copy available at http://mdz-nbn-resolving.de/urn:nbn:de:bvb:12-bsb00030432-6. Accessed 9 May 2022.

[13] For instance, (Gerardus 14th/15th cent.); 8r (the Sun); 9r (the Moon); 9v (the Moon and the Dragon). This manuscript in digitized in the Gallica-Repository.

[14] For instance, Ms. Latin Add. 447 2°, 49r–56r (Copenhagen, Royal Library), dating from around 1300, has these five diagrams, reproduced in (Gerardus 1974, Figs. 1–5). For another diagram of Venus and Mercury (Cambridge University Library, MS Ii.III.3, 82r), see (Müller 2008, Abb. 83).

[15] For instance in Ms. Latin Add. 447 2° (Copenhagen, Royal Library), 54r, and in MS Ii.III.3 (Cambridge University Library), 84r. See (Müller 2008, Abb. 85, 86).

[16] In the Ferrara edition (Gerardus 1472a), two whole pages, two two-third pages, and five half pages are left blank; in the Venice edition (Gerardus 1472b), only three whole pages and a half.

significant—as we have seen, some manuscripts of the *Theorica Gerardi* used the same device. Much more important is the fact that the diagrams bear titles (like the diagrams of the *Theoricae novae*) that sometimes add clarity to the text itself. In particular, in the section on the superior planets, the diagram is entitled "Theorica trium superiorum *et Veneris*" (Gerardus 1478a, b, e9r) (emphasis by the author), as in Peuerbach's book, whereas, in the text of the *Theorica Gerardi* and often in its diagrams, Venus is awkwardly associated with Mercury; and the Mercury diagram is entitled "Theory of Mercury, the most difficult of all others" ("Theoria Mercurii inter alia difficilior," e10v), which emphasizes that Mercury poses highly specific problems—a fact somewhat blurred in the text.

Moreover, the 1478 editor and his printer added diagrams that were not in the original canonical set. These diagrams are not remarkable in themselves. They are simplified sketches of elements that enter in the analysis of the movements, unlettered and without captions. The first, "Theorica medii motus" (e2v) shows the construction of the line necessary to measure the mean motion of a planet on the ecliptic in the simplest case: that of the Sun.[17] The next one, "Figura capitis et caudae draconis lunae" (e6r), simply shows the intersection of two circles at two opposite points (the circles are the ecliptic and the eccentric of the Moon, and the opposite points are the nodes, as can be deduced from the text). The third, "Figura minutorum proportionalium" (e9v), though almost unintelligible, is supposed to clarify the definition of the proportional minutes, in the case of the superior planets. The last diagram of the same kind, the figure of the stations and retrogadations (f6r), belongs to the traditional illustration of the *Theorica Gerardi*.

The Renner edition thus displayed a set of eight diagrams, well balanced between two groups: that of the complex figures of the planets, meant to represent the movements of each of these planets in their globality, and that of much simpler geometrical sketches, which show only one feature or mechanism. Of course, both types of diagrams existed in the manuscripts, which had often rough and incomplete figures drawn in the margins. But the influence of the *Theoricae novae* probably prompted the editor of the 1478 edition to increase the number of canonical diagrams; perhaps it helped him to perceive the usefulness of a wider range of diagrams, devoted to different functions.

In any case, if the Renner edition initiated an evolution, it soon petered out. The *Theoricae novae* remained without rival and were printed and reprinted in a long series of editions, all illustrated with copies or new versions of the original set of figures, and also with new diagrams added by successive editors and commentators (Pantin 2012). Peuerbach's treatise thus made more evident the crucial role of illustration in this kind of textbook in helping students to visualize Ptolemy's work.

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[17] The mean motion of the Sun ("medius motus Solis") is measured by the arc of the ecliptic between the first degree of Aries and the intersection of the ecliptic and the "line of the mean motion." This line begins at the center of the world and is parallel to the line that joins the center of the eccentric of the Sun to the center of the body of the Sun.

2.4 *Theorica*: The Meaning of a Term

The new treatise even modified—or rather clarified—the meaning of the word "theorica," and hence the meaning of its own title. Regiomontanus, who supervised the first printing, no longer used "theorica" (which we translate as "theory" for want of anything better) in the singular form, in the phrase "theorica planetarum" that could be understood as "science of the planetary motions," or in a collective sense, as "set of the theories of all the planets." Regiomontanus' edition, in all significant respects, is faithful to the manuscripts that can be traced directly to Peuerbach[18] (though Peuerbach's autograph is missing). However, its incipit differs from that of all five surviving manuscripts anterior to 1473. This incipit looks like a title: "Theoricae novae planetarum Georgii Purbachii astronomi celeberrimi," printed on two lines in capital letters. Regiomontanus reproduced this title with an advertisement-like addition ("with appropriate figures") on the first line of the trade list he published in 1474 or 1475: "Theoricae novae planetarum Georgii Purbachii astronomi celebratissimi: cum figurationibus oportunis" (Regiomontanus 1972, 533; Stromer 1980). By comparison, all the anterior manuscripts have incipits with the phrase "Theorica nova," obviously in the singular collective form, and in calculated opposition to the phrase "Theorica vetus."[19]

By modifying the phrase, and in the most conspicuous position, in the printed book, Regiomontanus probably wished to eliminate the vague and general use of the term "theorica." In medieval Latin, "theory" was most often termed "theoria." "Theorica," as a feminine noun, was also used to mean "speculative science," but it occurred more and more frequently in astronomical contexts and in the set phrase "theorica planetarum." Humanism increased this specialization of the word, for "theorica", as a feminine substantive, does not belong to classical Latin.

In the new plural use adopted in Peuerbach's title, as edited by Regiomontanus, "theoricae" clearly referred to the different geometrical models of the planets, and even, more precisely, to their diagrammatic representation. It thus reestablished a closer and more concrete relationship to its etymological root, *theôrein*: to observe.

We can even try to better determine to what extent Regiomontanus' use of the term was, in his time, purposefully innovative. In the three earliest manuscripts of Peuerbach's treatise, there is no indication of a possible shift in the meaning of the word "theorica." In particular, the diagrams have no titles, and the successive "chapters" are introduced by a brief formula written in red: "De Sole," "De Luna," "De Capite draconis Lune," and so on (Malpangotto 2012, 252–253, 256). By contrast, in the manuscript presented to János Vitéz (ca. 1408–1472), counsellor of Matthias Corvinus (1443–1490), and archbishop of Esztergom from 1465, there are no titles

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[18] The most important manuscripts are Regiomontanus' autograph copy (Peuerbach 1454), and the copy bequeathed by Peuerbach to Bessarion in 1461 (Peuerbach 1461).

[19] On these five surviving manuscripts, see (Malpangotto 2012). On their incipits, see below. However, it must be noted that the explicits of the three earliest manuscripts, which are transcriptions of the 1454 lecture, use the plural, "Finiunt Theorice nove…" to refer to the whole set of "theories" devoted to different celestial objects (Malpangotto 2012, 352).

Table 2.1 Chapter titles of the Renner *Theorica Gerardi*, connected to the geometrical representations

Chapter title	Folio
Capitulum figurae Solis	e1r
Capitulum figurae Lunae	e2v
Capitulum figurae capitis et caudae draconis Lunae	e5v
Capitulum figurae trium superiorum scilicet Saturni Jovis et Martis	e6v
Capitulum figurae minutorum proportionalium	e9v
Capitulum figurae Mercurii et Veneris	e10r
Capitulum de retrogradatione, statione et directione planetarum	f4v
Capitulum de latitudine et declinatione planetarum	f6v

for the different "chapters," but five diagrams have a title, written in golden capitals: "Theorica solis," "Theorica lune," "Theorica trium superiorum," "Theorica Veneris," and "Theorica Mercurii." However, it must be noted that this manuscript (Peuerbach 1455–1468), probably edited by Martin Bylica de Olkusz (1433–1493), deviates notably from the tradition initiated by Peuerbach and followed by Regiomontanus, as concerns the diagrams.[20]

In the manuscript bequeathed to Bessarion (Peuerbach 1461), the first diagrams of the "chapters" on the planets are made with volvelles, and much differ from the corresponding diagrams in the 1454 manuscripts.[21] These 1461 diagrams have titles written in red capitals and inscribed in phylacteries: "Theorica solis," "Theorica lunae," "Theorica trium superiorvm et Veneris," and "Theorica Mercurii." Each marks the beginning of the "chapter" it belongs to (Malpangotto 2012, 375, Figs. 10–11).

Then the Regiomontanus edition proposes a different mode of titling, much more consistent, which was adopted in subsequent editions. In it, all thirty diagrams have titles with a similar wording ("Theorica Solis," "Theorica axium and polorum," and so on), which distinguish them clearly from the titles of the "chapters" ("De Sole," "De Luna," "De passionibus planetarum diversis," and so on).

Here again, the editor of the Renner edition of the *Theorica Gerardi* (Gerardus 1478a, b) was probably influenced by Regiomontanus' innovations. He added a division in chapters with titles that express the prominent role of the geometrical representations (Table 2.1).

[20] The images called "Theorica" are in 2r, 4v, 7r, 8v, 10r. The dates I give for the manuscript correspond to the first encounter of Vitéz with Peuerbach and Regiomontanus in Vienna (1455) and to the last year Bylica was in the service of Vitéz before being appointed as Matthias Corvinus' astrologer (1468). This manuscript was among the books and instruments bequeathed by Bylica to the university of Krakow. See also (Birkenmajer 1893, 41–42; Malpangotto 2012, 363, Fig. 5). On the illustration of this manuscript, see below, Sect. 2.7.

[21] On these volvelles, see Sect. 2.7 below.

Table 2.2 Diagram titles of the Renner *Theorica Gerardi*

Diagram title	Folio
Theorica Solis	e2r
Theorica medii motus planetarum	e2v
Theorica Lunae	e4r
Figura capitis et caudae draconis lunae	e6r
Theorica trium superiorum et Veneris	e9r
Figura minutorum proportionalium	e9v
Theorica Mercurii inter alia difficilior	e10v
Figura retrogradationis, stationis et directionis planetarum	f6r

The eight diagrams of the Renner edition also had titles, and these titles marked the difference between the representation of a complete planetary model ("Theorica") and that of a particular element of such models ("Figura") (Table 2.2).

Thus, it seems possible to conclude that Regiomontanus made an effort to give "theorica" a clearer definition and a more specific function. By using the term so steadily and consistently to refer to all the diagrammatic representations in his edition of Peuerbach's treatise, he went as far as to propose the systematic replacement of "figura" by "theorica" in the case of the analysis of planetary motions.

This choice, though rather radical, had some roots in the habits of the language of astronomers. In the Middle Ages, "theorica" was already linked to the field of the geometrical analysis of planetary motions, as we have seen, as well as to the notion of "model." A few years after Peuerbach's momentous lectures at the Vienna *Collegium civium*, short treatises circulated at the universities of Erfurt, Leipzig, and Frankfurt. They described a new kind of "equatorium," a geometrical model of planetary motions, made in brass, in wood, or most often in parchment, cardboard, or paper, to serve as a calculating instrument: an "equatorium" helps to find the position of a given planet with the aid of threads and rotating wheels, much more easily than when using astronomical tables alone. The treatises were entitled *Theorice novelle*, or *Theorice nove* in the plural form, which suggests a close association between "theorica," as a term designating a specific object, and this kind of model, midway between a geometrical description and a material instrument.[22]

This established link explains why in the Vitéz and Bessarion manuscripts of the *Theoricae novae* (and in the Renner 1478 edition of the *Theorica Gerardi*) the main diagrams of the planets are labeled "Theorica Solis," and so on. It indicates an evolution that probably accelerated after 1450.[23] For, though no extensive survey

[22] According to Poulle (Poulle 1980, 377–393) these treatises, sometimes accompanied with paper instruments, are datable to between 1458 and the beginning of the 1470s. These "Theorice" were called "nove" to differentiate them from Campanus de Novara's *Theorica*, which combines a theory of planets and the construction of an "equatorium" (see Sect. 2.7 below).

[23] Poulle observed that the fifteenth century was "à coup sûr, par excellence, le siècle des équatoires," and that in the second half of this century, there even appeared "enthusiasm" for a certain type of "equatoria," which were then introduced in the syllabus of some German universities (under

has been made on this point, it seems that in the fourteenth- and fifteenth-century manuscripts of the *Theorica Gerardi*, the diagrams, when they were labeled at all, were labeled "figura"—most often in the set phrases "Figura motus solis," "Figura motus lunae," and so on.[24]

By giving a title to all the diagrams of Peuerbach's treatise, and by always using "theorica" in these titles, Regiomontanus initiated a new practice, which was imitated in subsequent editions of the *Theoricae novae* for about half a century.[25] Then the rule was loosened. In the Paris edition, supervised by Oronce Finé (1494–1555), no diagram has a title (Peuerbach 1525, 1534); the titles are replaced by legends. Finé has tried to impose his own layout on the book, in particular he boasted on the title page that he had considerably improved the illustration, as well as the text.

The editions prepared in Germany, first by Peter Apian (1495–1552), then by Jacob Milich (1501–1559) for a Wittenberg printer, are more faithful to the tradition initiated by Regiomontanus (Peuerbach 1528, 1535): the diagrams inherited from this tradition, or directly inspired by it, are, with a few exceptions, labeled "Theorica" in the "chapters" on the planets and in the last section, "De motu octavae sphaerae;" but all but one of the diagrams in the "chapters" "On the passions of the planets" ("De passionibus planetarum") and "On declination and latitude" ("De declinatione et latitudine"), as well as all the diagrams added in the "chapters" on the planets to clarify certain points of the description, are without titles. A partition is thus established between the "theoricae" proper, that is the diagrams that are essential to the modelization of the movements of the celestial orbs, and the other diagrams, which concern particular aspects or whose function is auxiliary.

In the Wittenberg editions with commentary by Erasmus Reinhold (1511–1553), this division of the diagrams into categories is carried further. The use of "theorica" in the diagrams' titles remains the same, or about the same, as it was in the Apian and Milich editions. But, though Reinhold has introduced many new diagrams in his commentaries (or "scholia"), the total number of diagrams without titles has decreased, for new categories have appeared. Two diagrams are called "instrumentum" (see Sect. 2.7 below) and Reinhold uses "typus" for the representations of the eclipses. This suggests that they are documentary images, for "typus," sometimes a synonym of "woodcut," is often found in the captions of the figures of books of natural history.

More importantly, a large number of diagrams are called "schema" ("form" or "figure" in Greek), a term sometimes spelled in Greek and associated with an other

the title "Theorice novelle") (Poulle 1980, 737). It is tempting to establish a link between this observation and the evolution in the use of the term "theorica."

[24] Manuscripts of the *Theorica Gerardi* are, for instance, in Copenhagen, Royal Library, Ms. Latin Add. 447 2°, and in Cambridge University Library, MS Ii.III.3, see (Müller 2008, Abb. 80, 82, 83); or in Paris (Gerardus 14th cent.; Gerardus 14th/15th cent.): both manuscripts are digitized in the Gallica-Repository.

[25] Using "theorica" in the titles of the diagram applies to the editions without commentaries: (Peuerbach 1482, 1485, 1488), and so on.

greek term, *apodeixis*.[26] *Apodeixis* (from *deiknein*, “to show”) means “demonstration” in Aristotle’s logic, as opposed to the dialectical reasoning that does not produce sure knowledge. The term is linked to the notion of evidence, and also of visuality. Reinhold’s diagrams and their captions were faithfully copied in the Paris editions that gave them a wider audience (Peuerbach 1553a, 1556).

In Regiomontanus’ edition, the uniform wording of the titles of the diagrams probably had a double purpose: to emphasize the importance of illustration in the *Theories of the planets*, and to draw attention to the singularity of the representation of the models of celestial movements among the variety of geometrical diagrams. By introducing some diversity in the diagram titles of his own editions (Peuerbach 1542, 1553b), Reinhold did not alter this original intent: the term “theorica” retained, and even refined, its specificity, and the diverse aspects of the relationship between visual representation and geometrical analysis, in the case of the theories of planets, were better clarified.

2.5 The “Theoricae” as “Pictures” of Heavens: The Elusive Relationship between Geometrical Abstraction, Modelization, and Concrete Reality

In Reinhold’s editions, the “schemas” most often show methods for understanding an important feature of the mechanism of a celestial movement. A large portion of them are lettered and accompanied by detailed legends; they do not simply illustrate the text, but play the role of visual demonstrations. For instance, the “theoricae” (in Regiomontanus’ edition) of the “proportional minutes” are called “schemas” in Reinhold’s edition, and so are, among the added diagrams, the “schemas of the three points” (one for the Moon, one for the three superior planets). The “three points” are the mean and the true apogees of the epicycle, and a third point called “punctum cavitatis” (“point of the cavity” or “point of the concavity”) by Peuerbach—a phrase that does not appear in the *Theorica Gerardi*, which runs quickly through the analysis of the motion of the epicycles.

In the case of the Moon (Fig. 2.3), the schema shows six successive positions (A, B, C, D, E, F) of the epicycle, which rotates in its eccentric deferent orb, represented by three white circles nested within two “deformed” orbs. The outermost circle, like in almost all diagrams of the *Theoricae planetarum*, is the ecliptic, whose center (T) is the center of the world. The small interior circle is the circle described by the center of the eccentric deferent (S), as it moves around the center of the world (T). The vertical line is the axis of the eccentric deferent of the moon that passes

[26] [in Greek:] “*schema kai apodeixis* longitudinum mediarum” (Peuerbach 1542, L4v): title of the diagram that shows the method for finding the mean longitudes of the three superior planets.

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concauitatis, sicut hæc in textu sunt explicata. Intelligimus autem superficiem planam epicycli existere ac rotari in quodam concauo superficiei planæ eccentrici, quod per se est immobile, quia tantum ad motum eccentrici circumfertur. Huic item plano eccentrici, si tantam tribuimus vel crassiciem, vel latitudinem versus centrum, quantus est diameter epicycli, necesse est circumferentiam epicycli contingere superficiem concauam superioris deferentis augem eccen. in vno tantum puncto, per ij. tertij ele. ecc. Quare etiam punctum contactus vocari potest illud punctum concauitatis, quod super auge vera ac media epi. collocatur, dum centrum epic. habet apogion aut perigion eccentrici.

SCHEMA TRIVM PVNCTORVM.

Fig. 2.3 The "three points" in the movement of the epicycle of the Moon. Cambridge, Trinity College, Wren Library. S.3.117. Reproduced by kind permission of the Master and Fellows of Trinity College, Cambridge. From (Peuerbach 1553a, 31r)

through the apogee and perigee of this deferent, the center of the eccentric deferent and the center of the world. This axis also passes through V, the "opposite point" ("punctum oppositum"),[27] situated on the little circle and diametrically opposed

[27] The "punctum oppositum," a term that belongs specifically to the theory of the Moon, plays a similar role as the equant point ("punctum aequans") in theories of other planets (the Sun excepted): with respect to this point, the center of the epicycle, carried by the eccentric deferent, is supposed to have a constant circular movement.

to S. The "three points" (M, P, V)[28] are marked on the epicycle by lines that all pass through the center of this epicycle but originate, respectively, at the center of the world, at the "opposite point," and in the center of the deferent. The first line (from T) encounters the epicycle in V, the "true apogee of the epicycle" ("aux vera epicycli"), the second line (from the "opposite point") ends in M, the "mean apogee of the epicycle" ("aux media epicycli"),[29] and a third line (from S), ends in P, the "point of the cavity of the epicycle." According to Peuerbach, the true and mean apogees of the epicycle are always "under" this last point ("sub quo") "when the center of the epicycle is in the apogee or perigee of the deferent" (Peuerbach 1987, 15), that is on the axis of this deferent. The schema, which did not exist before the Reinhold editions, effectively shows at first sight that when the center of the epicycle is on the axis, the three lines merge into one. In every other positions of the epicycle, the lines diverge, and V, the "true apogee," is always between the "mean apogee" M and the "point of the cavity" P (though M and P exchange their position after passing through the axis). To consider this "point of the cavity," which plays no role in the computation of the movement of the epicycle, gives a more concrete notion of this movement. This is probably why Reinhold has added the schema and written *scholia* to clarify the corresponding passage in the *Theoricae novae* "that is one of the most difficult" ("unus…ex difficilimis"). He begins by explaining the meaning of the unusual phrase "punctum cavitatis," as used by Peuerbach, and thus moves from pure geometry to a reflection on the mechanical problems of the construction of a model:

> We understand that the plane of the epicycle remains and rotates in some cavity of the plane of the eccentric;[30] [the cavity] is, by itself, immobile, as it is only carried by the movement of the eccentric. If we attribute to this plane of the eccentric as much thickness, or width in the direction of its center, as the diameter of the epicycle,[31] then the circumference of the epicycle will necessarily touch the concave surface of the upper deferent of the apogee of

[28] In sixteenth-century diagrams, it can occur that the same letter ("V" in this example) corresponds to two different points, as long as it does not cause inextricable ambiguity.

[29] The difference between the "true" (real and actual) movement or position of a celestial point or body, and its "mean" movement and position was an essential feature of the theories of planets. As the "true" celestial movements were irregular, due to diverse anomalies, mean motions, by which the celestial circles (and the bodies they carried) were supposed to rotate equably, had to be calculated. The difference between a "true" and a "mean" motion was called the "equation" ("equatio" or "aequatio").

[30] In Peuerbach's general description of the configuration of the sphere of the Moon, the epicycle is described not as a circle but as a "little sphere…immersed into the depth of the third orb [= the eccentric deferent], in which epicycle the body of the Moon is fixed:" "…sphaerulam…profunditati orbis tercii immersam in quo quidem epicyclo corpus lunare figitur" (Peuerbach ca 1473, 2v).

[31] It simply means that the thickness of the eccentric deferent orb exactly corresponds to the diameter of the epicycle, as shown in the diagram.

the eccentric[32] at only one point, according to Euclid, (*Elements*, III, 2, etc.).[33] That is also why this "point of the cavity" can be called the "point of contact," which is over (*super*) the true and mean apogees of the epicycle, when the center of the epicycle is at the apogee or perigee of the eccentric.[34]

According to pure geometry, M, V, and P merge at one unique point when the center of the epicycle is on the axis of the deferent, but Reinhold keeps Peuerbach's idea that P, the "point of the cavity," which belongs to the eccentric orb and touches the upper "deformed" orb, is "over" the other two, which belong to the epicycle nested inside the "cavity:" content and container must remain distinct. The phrase "point of contact," meaning the point where the true and mean apogees of the epicycle touch the concave border of the upper "deformed" orb, expresses this idea more clearly than "point of the cavity." The letters in the diagram are so disposed as to emphasize it—with some exaggeration.

Not all the diagrams in the *Theoricae novae* feature figures (with their legends and explanations) that could serve as bridges between abstract geometry and modelization efforts. But it was widely acknowledged that they were a support to the imagination, and that imagination played a crucial role in the theories of the planets.

One of the translators of the treatise *On the configuration of the world* had his patron, King Alfonso X of Castile (1221–1284), praise Ibn al-Haytham for having "imagined all that exist indeed universally in the celestial bodies, and in the heavens that are singularly imagined."[35] Some time later, Roger Bacon (ca. 1220–1294), in his *Opus tertium* and in his *De coelestibus*, used the depreciative "ymaginatio modernorum" to refer to the planetary models conceived in his time by some mathematicians (whose names he did not mention), under the probable influence of Ibn al-Haytham's treatise (Bacon 1909, 125; 1913, 438; Lerner 1996, 115–116).

But imagination has two sides: it is either a deceptive forger of illusions, or an indispensable tool for thinking and knowing. It has been theorized by the philosophers of the mind since antiquity (Bianchi and Fattori 1986; Lagerlund 2007; Panaccio

[32] The two "deferents of the apogee of the eccentric of the Moon" are the "deformed" orbs between which the eccentric orb is situated. They carry with them the apogee of the eccentric as they "move westward together, uniformly about the center of the world, by about eleven degrees and twelve minutes beyond the diurnal movement in a natural day" (Peuerbach 1987, 12). The "upper deferent of the apogee of the eccentric" is above the eccentric deferent.

[33] As the text concerns two circles (the epicycle and the concave surface of the upper deferent of the apogee) that meet at one point, the reference must be *Elements* III, def. 3 and prop. 6, 11, 13 (Euclid 1956, II, 1, 13, 24–25, 32–33).

[34] "Intelligimus autem superficiem planam epicycli existere ac rotari in quodam concavo superficiei planae eccentrici, quod per se est immobile, quia tantum ad motum eccentrici circumfertur. Huic item plano eccentrici, si tantam tribuimus vel crassitiem, vel latitudinem versus centrum, quantus est diameter epicycli, necesse est, circumferentiam epicycli contingere superficiem concavam superioris deferentis augem eccen <trici> in uno tantum puncto, per ii. tertii ele. etc. Quare etiam punctum contactus vocari potest illud punctum concavitatis, quod super auge vera ac media epi <cycli> collocatur, dum centrum epic <ycli> habet apogion aut perigion eccentrici (Peuerbach 1542, G8v–H1r, 1553a, 31r).

[35] "…est ymaginatus totum quod equidem est in corporibus celestibus universaliter et in celis singulariter imaginatis" (Mancha 1990, 143; Lerner 1996, 292–293).

2010; Schofield 1992; Spruit 1994–1995). The Renaissance editors and commentators of Peuerbach held a more positive view of the "imaginations" proposed in the *Theoricae novae*. They sometimes articulated the link between the non-demonstrative character of the textbook and its reliance on visual representation. At the beginning of his commentary on the *Theoricae novae*, Sylvester de Prierio (1456–1523) states that this compendium of the *Almagest* omits demonstrations in order to transmit knowledge "to the simple faith and to the *imagination,*" in such a manner "that the disposition and movement of the celestial spheres, and the meaning of the terms employed in the tables, can be *seen.*"[36]

According to Melanchthon, in the letter to Simon Grynaeus that introduces the new Wittenberg edition of the *Theoricae* (Peuerbach 1535), given that "elementary textbooks are needed in schools, no other manual is more necessary that these 'Theoricae,' as they are called, that is pictures of the celestial orbs."[37] This translation is repeated in Reinhold's dedication of his commentary to Albert of Brandenburg, duke of Prussia (1490–1568): "Theoricas, seu orbium picturas" (Peuerbach 1542, A6v).

This pictorial character of the "theoricae" had certain consequences, most of which were directly linked to the pedagogical function of the textbook—as if Peuerbach had been a precursor of Jan Comenius (1592–1670) and had conceived a kind of astronomical *Orbis pictus*. However, that did not exclude philosophical, and even religious implications. In the 1535 letter already quoted, Philipp Melanchthon refers to the Aristotelian distinction between "to hoti," knowledge that simply describes the facts as they are visible, and "to dioti" knowledge that explains them through in-depth inquiry into their causes,[38] it being understood that the former must be the first step toward the latter.

> Peuerbach did very wisely when he summarized in this summary Ptolemy's science of the motions of all the celestial orbs, in order to open the way for students to deal with the complete demonstrations…. Thus, when he sets up these pictures of the orbs, he delivers only [*Greek*] *to hoti*, so to speak. But he wishes that the causes why so many orbs are enumerated for each planet, and the observations by which so great a variety of movements has been noted, should be investigated in Ptolemy.[39]

This learning approach, aimed at acquiring a complete knowledge of celestial movements, was not an end in itself. Melanchthon and his Wittenberg disciples

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[36] "… probationibus geometricis sic ommissis ut nude fidei *ymaginationique* tradantur: quo celorum situs, motusque nec non et tabularum vocabula *conspici* possint" (Prierias 1514, A1r). Author's emphasis.

[37] "Scis autem in scholis opus esse Elementis, Nec alius libellus magis necessarius est, quam theoricae ut vocant, seu *picturae orbium coelestium*" (Peuerbach 1535, A3r). Author's emphasis.

[38] In the *Praefatio* of his commentary, Reinhold explains the distinction and gives this definition of *to hoti* teaching: this is "when only nude and brief precepts, or maxims or rules are proposed, without the causes and demonstrations" ("cum videlicet nuda ac brevia quaedam praecepta, sive sententiae aut regulae proponuntur sine causis atque demonstrationibus…") (Peuerbach 1542, C4r–v).

[39] "Purbachius prudentissime in hanc epitomen contraxit Ptolemaei doctrinam de omnium orbium coelestium motibus, ut studiosis aditum ad integras disputationes patefaceret…Itaque dum hic *picturas* orbium instituit, tantum [*Greek*:] *to hoti* ut ita dicam tradit. Causas vero, cur tot cujusque planetae orbes numerentur, et quibus observationibus tanta varietas animadversa sit motuum, postea vult ex Ptolemaeo peti…" (Peuerbach 1535, A6v). Author's emphasis.

considered astronomy a deadly weapon against atheism because the beauty and complex regularity of heavenly revolutions, alongside their observable effects in this sublunary world, led to the recognition of divine Providence (Caroti 1986; Kusukawa 1995, 124–173; Brosseder 2004, 2005). The "theoricae" could thus be viewed not only as useful pedagogical images but also as a means for contemplating the geometrical order of the cosmos; and Melanchthon, in his prefatory letter, associates the praise of Peuerbach with an apology of Christian astronomy and astrology.

> Moreover, as Plato said, "God always does geometry,"[40] that is, he governs this our world by measuring everything according to a most certain movement, so that we could delight in that most beautiful geometry that shows us the divinity, by considering in our turn the lines drawn by this supreme Artist.[41]

However, the fact that Peuerbach's "pictures" led to an understanding of the beauty of cosmic geometry did not implicate that they represented the real "configuration of the world" (to borrow Ibn al-Haytham's title, as understood by its Western translators). All Peuerbach's readers did not share the same position on this point.

In the earliest manuscripts of the *Theoricae novae*, there is no ambiguity. With the notable exception of the manuscript bequeathed to Bessarion (Peuerbach 1461), they share the same incipit: "So begins the new theory that reveals the *real* disposition and motion of the spheres."[42] Thus, the contrast was signaled from the outset between the "New theory" and the old one that remained within the limits of a strictly geometrical exposition.

Diagrams played a key role in Peuerbach's project, not only because they revealed the originality of the treatise, as already mentioned in Sect. 2.3, but also because images can possess a certain degree of physical existence, at least as credible representations of physical things. They proved that the complex combinations of eccentrics and epicycles, conceived by Ptolemy, could be inserted into a system of contiguous orbs, both mechanically valid (as a well-regulated clock) and compatible with Aristotle's general description of the real cosmos. The figures of the *Theoricæ novae* that showed the main pieces of this clockwork thus possessed a cosmological value and hence some philosophical legitimacy.

However, in Regiomontanus' edition, the original incipit had disappeared, which left the book open to interpretation. Regiomontanus himself had an ambivalent stance on the issue. His published work makes him appear as an active rehabilitator of Ptolemaic astronomy and an admiring disciple of his master Peuerbach, but some of his letters and, above all, his unpublished *Defense of Theon against George of*

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[40] *Theon aei geometrein*. This saying is attributed to Plato by Plutarch in one of his *Symposiacs*, "What was meant by saying God is always doing geometry" (718c–720c). In this passage, Melanchthon probably also refers to Plato's *Timaeus* where the necessary, harmonious, and regular motion of heaven is given as the model that men must contemplate to keep their souls in tune with it (*Timaeus*, 45b–46a, 47b).

[41] "Quin potius, ut Plato dixit, deum semper [in Greek:] *geômetrein*, hoc est certissimo motu omnia metientem, gubernare haec inferiora, ita nos vicissim hujus summi artificis lineas considerantes, hac pulcherrima geometria nos oblectemus, quae divinitatem nobis ostendit" (Peuerbach 1535, A4v).

[42] "Incipit Theorica nova *realem* sperarum habitudinem atque motum…declarans" (Malpangotto 2012, 352, 361). Author's emphasis.

Trebizond, studied by Michael Shank, reveal that he was critical of the astronomy of eccentrics and epicycles and tried to conceive a homocentrist astronomy that would possess the accuracy and predictive power of the models described in the *Almagest*—which the medieval homocentrists had failed to do. As Regiomontanus wished to find the real configuration of the world, he much preferred Peuerbach's *Theoricae novae*, with their nearly three-dimensional models, to the *Theorica Gerardi*, but all the same, he did not think that they showed the "*real* disposition…of the spheres," and he regarded them as second best (Shank 1998, 2002).

Regiomontanus' successors could therefore take varying positions on the matter, according to their philosophical stance. Two early commentators of the *Theoricae novae*, Francesco Capuano (fifteenth cent.) and Silvestro Mazzolini da Prierio, or Sylvester Prierias (ca. 1456–1523), used the treatise to defend opposite positions (Peuerbach 1495; Prierias 1514). The former affirmed the reality of the orbs described by Peuerbach to better defend Ptolemy against the "Averroist" attack of the homocentrist Alessandro Achillini (ca. 1463–1512), while the latter, who had "Averroist" sympathies,[43] dwelt on their fictitious nature (Lerner 1996, 129; Pantin 2012, 8–10). Further investigation would lead to the problem of the realism of hypotheses, which certainly touches on the question of the diagrams, but is much broader.

Some remarks from Reinhold show in any case that certain authors had a subtle perception of the different ways by which the "theoricae" allowed one to glimpse the truth of things. Like Melanchthon, Reinhold enlarges the Platonic theme of the contemplation of celestial geometry, but he enriches it by linking it with the construction of mechanical models—probably in full knowledge that he thus opposed Plato (ca. 428–348 BCE).[44]

> I hear that the Ancients made planetary automata. We ourselves, we have seen machines, made with wonderful art, which contained the daily motions of all the planets. But, certainly, to propose this brief summary of the movements has required more intelligence. I am sure that the craftsmen of that time, who made these machines, had taken thence their model. It was necessary to look at this *Idea* to make the courses of the stars sometimes slower and sometimes swifter, to show some stars move forward, others recede, some deviate southward, others northward. Having observed a kind of picture of such a variety in these *theoricae*, they built afterwards their machines according to this *Idea.*[45]

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[43] Mazzolini de Prierio was a friend of the "Averroist" Agostino Nifo, see (Tavuzzi 1997, 97–104).

[44] In *Republic* VII (522c–530c), Plato insists that the mathematical sciences practiced by the philosopher must remain purely speculative, see also (*Philebus*, 56d–57b). In Plutarch's *What was meant by saying God is always doing geometry* (*Symposium*, VIII, 2, 718c–720c), one of the characters notes that Plato forbade to mix mathematics with any mechanical device (718e). Plutarch explains, in the *Life of Marcellus* (14: 4–6; 17: 4–5), that for that reason Archimedes considered his machines to be simple recreation and never consented to leave any treatise on them.

[45] "Audio fabrefacta esse a veteribus planetarum Automata. Vidimus et ipsi mira arte factas machinas, quae motus quotidianos omnium planetarum continebant. Sed profecto majoris ingenii fuit hanc tradere brevem motuum summam. Nec dubito, quin hujus aetatis artifices, qui machinas illas fabricarunt, hinc exemplum sumpserint. In hanc *Ideam* intueri necesse erat, cum itinera stellarum alias tardiora, alias celeriora facerent, cum alias progredi stellas, alias regredi, evagari alias in austrum, alias in arcton ostenderent. Hujus tantae varietatis, quasi *picturam* in his theoricis *spectantes*, postea machinas ad hanc *Ideam* accommodarunt" (Peuerbach 1542, A7v). Author's emphasis.

Idea, a Platonic term, originally refers to the essence of things that can be intuited by the mind but cannot be realized in matter except as an inferior copy. The spheres and planetaries made in antiquity and in modern times are a Ciceronian and humanist topos related to the praise of the excellence and divinity of the human mind (Pantin 1995, 86–98). Here, they are supposed to have been built after their makers contemplated the *Idea* provided by the *theoricae*. In hyperbole, the text conveys the notion that the *Theories of the planets* are truthful pictures of the heavens, whose genuineness is further attested by the wonderful craftsmanship of the planetaries. However, Reinhold goes on to deny any intention to comment on the physical organization of the world.

> For what is more absurd than to disturb the inventions of geometry with conjectures on physical matters? For disturbing geometrical demonstrations with the delusions of conjectures is not only vanity of the mind, as Plato said, but even hateful impudence.[46]

2.6 The Images as Pedagogical Summaries and Glossaries of Technical Terms

The *Theoricae novae planetarum*, as "pictures" of the celestial orbs and movements, thus had a philosophical background, but that did not interfere with their primary function: to provide a pedagogical summary of Ptolemy's geometrical analysis of the planetary motions, and to be a first introduction to astronomical practice. Ultimately, the reader of this manual was to become capable of computing celestial positions with the aid of astronomical tables; those referred to in the *Theoricae novae* belonged to the Alphonsine corpus,[47] which had progressively supplanted the *Toledan tables* from the fourteenth century (Poulle 1981; Pedersen 2002). The corpus contained numerous sets of tables that varied in number and in type (calendars, chronologies, tables of eclipses, tables of the prime mobile, planetary tables etc.), in their presentation, in their instructions for use, and in their reference meridian.[48]

The tables consisted of numerical series, laid out in columns, under cryptic headings whose understanding required the mastery of a specific vocabulary. They were accompanied by *Canones* that gave key information on how they had been made and the rules for using them, but the relationship between the numerical series

[46] "Quid est enim insulsius, quam inventa geometrica exagitare conjecturis physicorum? Non solum vanitas est ingenii, ut Plato dixit, sed etiam petulantia digna odio, conturbare geometricas demonstrationes praestigiis conjecturarum" (Peuerbach 1542, A8r).

[47] The origin of the *Alphonsine tables*, attributed to a group of astronomers working under the patronage of Alfonso X around 1270, is discussed because there is no surviving manuscript of their Castilian original (Poulle 1988; Chabás and Goldstein 2003; Swerdlow 2004). The *Tabulae alphonsinae* began to circulate in Latin from 1320, with canons prepared by Parisian astronomers Jean de Murs, Jean de Lignères, and Johannes de Saxonia.

[48] For a typology of the tables and indications on their organization and use, see (Poulle 1981, 1984; Chabás 2012; Chabás and Goldstein 2012); on the tables in the sixteenth century, see (Poulle and Savoie 1988).

and the actual mechanism of celestial motions was not explained. The latter task was performed by the *Theoricae*, which thus established a correspondence between the numerical and geometrical expressions of the celestial motions. Moreover, they provided definitions, both verbal and visual, of all the specific terms used in the tables.

The definitions of these technical terms were inserted in the text of the *Theorica communis* and occasionally gathered in separate glossaries (Pedersen 1973; Poulle 1987). The *Theoricae novae* modernized these definitions without drastically changing the technical vocabulary. Peuerbach even took care to quote and explain some obsolete formulas, so as not to confuse readers who were used to the old *Theory*. For instance, the first sentence of the *Theorica Gerardi* defines the eccentric circle as a circle "vel egresse cuspidis, vel egredientis centri:" "with a displaced cusp, or an outgoing center" (Gerard 1974, 452). In his opening paragraph, Peuerbach prefers a more usual definition, but later, when explaining that the Sun, on its eccentric, moves uniformly about the center of this eccentric, but nonuniformly about the center of the world, he adds that "for this reason" ("itaque") the eccentric circle is called "vel egresse cuspidis, vel egredientis centri circulus" (Peuerbach ca. 1473, 2r). The old formula, though useless, had to be clarified, given the importance of its terminological legacy.

The earliest manuscripts of the *Theoricae novae* make clear in their incipit that the explanation of technical vocabulary is a primary aim of the work: "Begins the new theorica…with the terms in the tables."[49] Reinhold accordingly adds complements to the definition given by Melanchthon: the *Theoricae* are not only "pictures of the orbs," they are, at the same time, "nomenclatures and summaries of the movements" ("et nomenclaturas, et motuum summas") (Peuerbach 1542, A6v).

The figures helped to perform this task. In astronomy, as in other disciplines like cartography (Woodward 1987) or medicine (Nutton 2001; Pantin 2013), the images were often used to facilitate the memorization of lists of names. In the manuscripts of the *Theorica Gerardi*, the diagrams often have at least some labeled lines, circles, or arcs (Müller 2008, Abb. 81–83; Gerard 1974, Figs. 2–5).

The thirty large diagrams of the *Theoricae novae*, which circulated in printed form, opened new possibilities as soon as technical difficulties were solved. For it was not easy to print a complex geometrical diagram and detailed labels, whatever the method chosen: be it cutting the text and the figure in relief on the same woodblock (like in xylographic books) or on a plate of metal—metalcut was a technique used in south Germany in the second half of the fifteenth century (Field 1965)—or inserting type in holes made in the woodcuts, or using metallic relief mirror-images of the diagrams with their letters, produced as when casting type fonts. Michael Shank has argued that the diagrams of the 1475 *Disputationes* were printed with this last technique (Shank 2012).

The *Theoricae novae* was the first illustrated astronomical book printed in the West, and its printing was a technological adventure that required solutions that had never been utilized before. Its figures are different from the relatively small

[49] "Incipit Theorica nova…cum terminis tabularum," the missing part of this incipit is quoted above.

geometrical diagrams of the *Disputationes*: drawn into square borders, they occupy about two-thirds of the page, and are situated either at the bottom or at the top of the pages instead of being embedded in the text. I will not hazard a guess on the method with which they were printed. Anyway, they often bore labels, very similar to those in the manuscript diagrams of the *Theorica Gerardi*. The centers were indicated ("c. mundi," "c. deferentis," "c. equantis"), as were the poles and the axes in the "theoricas" devoted to this matter; for instance in the case of the superior planets (Fig. 2.2):

M[eridionalis] polus ecliptice

S[eptentrionalis] polus ecliptice

polus deferentis

aux (= apogee) oppositum augis (= perigee)

superficies plana ecliptice

superficies plana deferentis

In other diagrams, other important points, lines, and circles were indicated, like "principium arietis" (the first degree of Aries), "linea medii motus" and "linea veri motus" (in the diagrams of the lines and motions), and the different ecliptics and their poles in the "De motu octavae sphaerae." However, these labels were limited to essential indications and were far from including the main technical vocabulary.

At the turn of the century, technical improvements almost allowed for a visual encyclopedia of astronomical knowledge. In 1503 in Freiburg im Breisgau, Gregor Reisch (d. 1525) published the *Margarita philosophia*, a compendium of university learning that contained (among many other matters) a summary of the *Theoricae novae planetarum*. At this date, after the Nuremberg princeps edition, Peuerbach's treatise had only been printed in Italy, and Reisch's *Margarita* initiated a tradition in Germany: its planetary diagrams influenced Peter Apian (Peuerbach 1528; Pantin 2012, 15–16) and through him the Wittenberg editors of Peuerbach.

In book VII of the *Margarita*, much information on planetary motions is condensed in three chapters that deal with the problem of terminology. The first one (Chap. 37), "On the meaning of the terms of astronomical tables" ("De significatione terminorum tabularum astronomicarum"), contains a series of definitions corresponding to the case of the Sun: "aux" (apogee), "oppositum augis" (perigee), "equatio," and so on. At the end, the reader is invited to look at a carefully labeled diagram: "you will be able to see all these things on the figure before your eyes" ("haec singula in subjecta oculis videre poteris descriptione"). The next chapters are similar and concern the Moon, then "the other planets" (the superior planets): "De terminis tabularibus in reliquis planetis" (Reisch 1503, o1r–o3v).

The diagram (Fig. 2.4) is loosely based on the "theorica of the lines and motions" of the superior planets in Regiomontanus' edition and in the subsequent Venetian editions. However, it adds elements taken from other diagrams (the "theorica of the orbs" and the "theorica of proportional minutes") to obtain a more synthetic figure—it thus somehow returns to the model of the diagrams of the *Theorica Gerardi*.

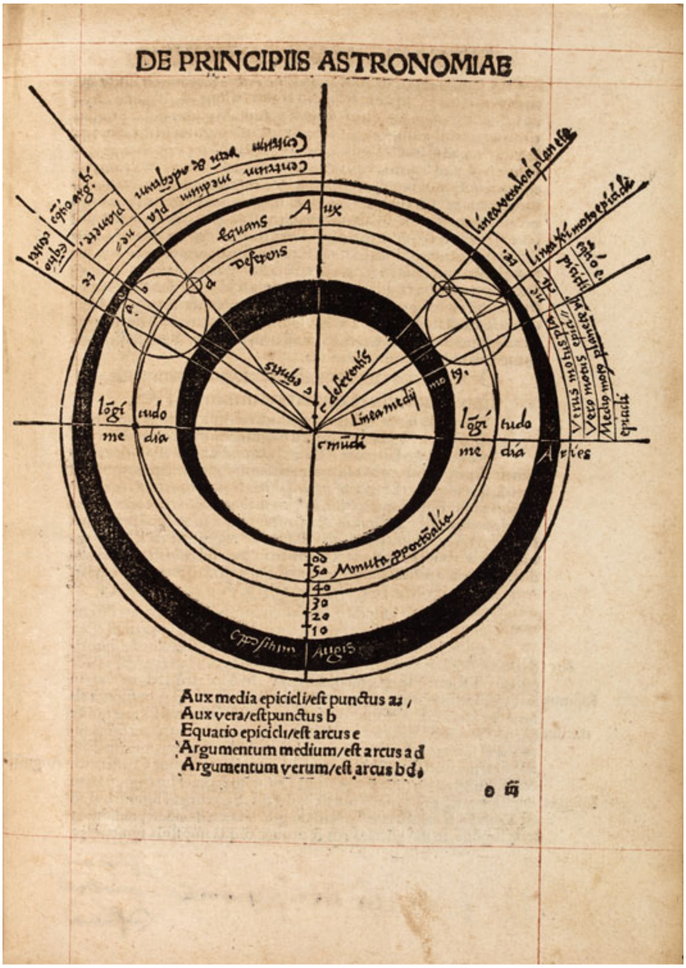

Fig. 2.4 The terms in the tables concerning the superior planets. Cambridge University Library. Norton.c.32. By permission of the Syndics of Cambridge University Library. From (Reisch 1503, o3r)

The *Margarita* diagram shows the system of three orbs, described by Peuerbach for the superior planets, with the "deformed" orbs blackened for better clarity and the eccentric deferent orb (that contains the epicycle) slightly enlarged to make the labels more legible. The outermost circle represents the ecliptic: the beginning of Aries is marked ("Aries"). The vertical line is the axis that passes through the apogee and perigee of the eccentric deferent of the planet ("Aux", "Oppositum Augis"), and the three aligned centers of the equant circle ("c. equantis"), of the eccentric deferent ("c. deferentis"), and of the world ("c. mundi"). The line that crosses it at right angles at the center of the world indicates the points of the eccentric deferent that are at middle distance from the Earth (between the apogee and perigee). These points, marked “longitudo media” (mean longitudes) are also the intersection points of the equant circle (“Equans”) and of the deferent circle (“Deferens”), the circle in the middle of the eccentric orb on which is fixed the center of the epicycle.

The terms concerning the epicycle are lettered on the diagram, and the corresponding labels are in the legend below. Point “a” is the mean apogee of the epicycle (“Aux media epicicli”), defined in the text as “the point of the epicycle marked by the line drawn from the center of the equant and passing through the center of the epicycle.”[50] Point “b” is the true apogee of the epicycle (“Aux vera”), marked “by the line drawn from the center of the world and passing through the center of the epicycle.”

Then come the specific terms used in the computation of the movements. The “line of the true motion of the epicycle” (“linea veri motus epicicli”) is drawn from the center of the world to the ecliptic, passing through the center of the epicycle. The “line of the true place of the planet”(“linea vera [*sic*] loci planete”) is drawn from the center of the world and passes through the body of the planet.

The line of the mean motion of the epicycle and of the planet (“linea medii motus”) is drawn from the center of the world to the ecliptic, parallel to the line from the center of the equant passing through the center of the epicycle. In the right part of the diagram (that with the label), this is not quite clear; the parallel line is incompletely drawn and does not meet the center of the equant, but in the left part both lines are correctly drawn.

All these lines mark on the ecliptic (the outward circle) the arcs that measure the different movements of the planet. The right part of the diagram shows the “true motion of the planet” (“Verus motus planete”), from “Aries” (first degree of the ecliptic) to the “linea vera loci planete;” the “true motion of the epicycle” (“Verus motus epicicli”), from “Aries” to the “linea veri motus epicicli;” and the “mean motion of the planet or the epicycle” (“Mediusmotus planetae vel epicycli”), from “Aries” to the “linea medii motus.” The small arc between the “linea veri motus epicicli” and the “linea medii motus” is labeled “equatio [motus] epicicli.”

Other arcs are shown in the left part of the diagram, whose lines and circles are symmetrical to those in the right part: the “mean center of the planet” (“centrum medium planetae”), measured eastward on the ecliptic from the apogee to the line of mean motion; the “true center of the planet” (“centrum verum et adequatum [*sic*] planetae”), from the apogee to the line of true motion; the “equation of the center” (“equatio centri”), which measures the difference between the mean and true “centers;” and the “equation of the argument” (“equatio argumenti”), between the line of the true place of the planet (that passes through the body of the planet) and the line of the true motion of the epicycle (which passes through the center of the epicycle).

The legend below adds the arcs measured on the epicycle, according to the direction of the movement of this epicycle: arc “e” (the letter is in white above arc “ab”)

[50] “…punctum epicicli per lineam a centro equantis, per centrum epicicli ducta designatum” (Reisch 1503, o2v).

is the “equation in the epicycle” (“equatio epicicli [= in epicyclo]”), between the mean and true apogees of the epicycle; arc ad is the “mean argument” of the planet (“Argumentum medium”), from the mean apogee of the epicycle to the body of the planet; arc bd is the “true argument” of the planet (“Argumentum verum”), from the true apogee of the epicycle to the body of the planet.

Lastly, the “Minuta proportionalia” are represented by the graduation (10, 20, 30, 40, 50, 60) marked along the line of the apogee in the inferior part of the eccentric orb, between the interior limit of the exterior “deformed” orb and the exterior limit of the interior “deformed” orb. Here the diagram is faulty, as the graduation ought to be placed between the eccentric deferent circle (that bears the center of the epicycle) and a point slightly below the exterior limit of the eccentric orb.[51]

In spite of some inaccuracies, this *Margarita* diagram is an efficacious visual glossary. Later editors of Peuerbach were influenced by this model, though they found easier to replace the labels on the diagram itself with letters referring to detailed legends. The *Margarita* similar diagram of the lines and motions of the superior planets was imitated by Peter Apian (Peuerbach 1528, titlepage and 32).[52] Three years before, Oronce Finé, in Paris, had simplified the diagram and reorganized the legend (Peuerbach 1525, 17v), followed by a Wittenberg editor (Peuerbach 1535, D6v–D7r). In the Reinhold edition, this same diagram (in the Wittenberg version) is presented as a means not only for memorizing the technical terms and understanding their meaning, but also for recapitulating all that had been explained before. The figure is preceded by this title: “Theorica in which are shown all the lines and arcs hitherto described.”[53] The legend is thus presented:

> Scholies of the preceding diagram.
>
> Now, in order that the terms hitherto explained should be more evident, it pleased us to expose simultaneously all their descriptions in one and the same figure.[54]

This is not an isolated example. Numerous of Reinhold’s scholies are diagrams accompanied by detailed legends, sometimes headed by titles like “Declaratio praecedentium vocabulorum” (L3v) or “Declaratio textus et figurae praecedentis” (L6r).

2.7 The *Theoricae* as Instruments

The *Theoricae*, as a series of annotated diagrams, thus enabled students of astronomy to acquire a basic knowledge and understanding of planetary motions and to move

[51] For a correct representation, see (Peuerbach 1542, M3r).

[52] Page 32 is the last of squire B and the legend has been truncated, probably due to a mistaken casting off.

[53] “Theorica in qua omnes lineae et arcus hactenus descripti ostendentur” (Peuerbach 1542, D6r).

[54] “Scholia praecedentis schematis. Nunc, ut vocabula hactenus explicata, fiant magis perspicua, libuit eorum descriptiones simul in una eademque figura declarare” (Peuerbach 1542, D6v–D7r).

from this abstract knowledge to practice with the first keys for using astronomical tables. A further step would have been to use the book itself as an instrument for computing celestial movements. The idea is not absurd, given the close relationship between the *Theoricae* and the books on "equatoria": both aimed at making geometrical models of the movements of each planet, the former for teaching purposes, the latter for computational practice.

Nothing impeded the use of the geometrical diagrams of a *Theorica* as the basis of an "equatorium." Under this logic, Campanus de Novara wrote a *Theorica* (ca. 1260), coupled with instructions for constructing and using an "equatorium"—the earliest known such description in Latin Europe. He showed how graduated disks, corresponding to the various movements of a planet, could be assembled as the rotating parts of an instrument and used to find motions without difficult calculations of data from astronomical tables. For instance, a disk could be set to the "medius motus" of a planet for a chosen date (found in the tables), and then the planet's "verus motus" could be marked, on the ecliptic scale etched on the rim, by a string stretched from the center of the instrument and passing through the point marking the planet on the epicycle disk. The reverse operation was of course possible, as the proper function of the instrument was to "equate" planetary motions.[55]

There are more than sixty extant manuscripts of Campanus' *Theorica*, which shows that the treatise had a wide circulation and was probably used in universities—in twenty manuscripts, it is accompanied by the *Theorica Gerardi* (Benjamin and Toomer 1971, 58). However, it did not set an example followed by other authors of *Theoricae* or books on "equatoria." Both traditions remained distinct and unbalanced in number, as the books on "equatoria" (that of Campanus excepted) had very limited circulation (Poulle 1981, 738–741).

Peuerbach's treatise thoroughly transformed and enriched the iconographical corpus of the *Theoricae* without changing the terms of the problem. The needs of pedagogy and those of astronomical computation were divergent. The diagrams of the *Theorica Gerardi*, though often encircled by a graduated ecliptic, could not keep up with the level of accuracy required of an "equatorium" (except for the theory of the Sun, the simplest of all); for one thing, they dealt with the three superior planets collectively, without regard for their specificities. The *Theoricae novae* even regressed on this issue. No diagram of the 1473 edition has a graduated circle. Moreover, the diagrams showing the arrangements of the orbs are nothing like the diagrams of the books on "equatoria," which look like the drawings of an astronomical clock (Benjamin and Toomer 1971, plates 1–3).

In a sense, Peuerbach's treatise clearly distanced itself from the tradition of the books on "equatoria."[56] There were several printed books of this last category in the first half of the sixteenth century (Finé 1526; Sarzosus 1526; Schöner 1521,

[55] On "equatio," the difference between a "true" and a "mean" motion, see above, Sect. 2.6. The purpose of an "equatorium" is clearly explained by Campanus in the prologue of his treatise (Benjamin and Toomer 1971, 138–143).

[56] Peuerbach wrote at least one short treatise on an "equatorium:" "Quoniam experimentum sermonum verorum." A copy of it in Regiomontanus' hand is in the same manuscript (Wien, ÖNB 5203) that contains Regiomontanus' 1454 copy of the *Theoricae novae*.

1522, 1524; Apian 1540). None of them was connected with the *Theoricae novae*. Only later did James Bassantin (d. 1568), a Scottish mathematician then settled in Lyons, take up Campanus' idea and push it farther. He published the *Astronomique discours* in French and dedicated it to queen Caterina de' Medici (1519–1589). It was composed of two mathematical treatises (on the table of sines and on rectilinear and spherical triangles), a treatise of the *Sphere*, and a *Theory of planets* (*La Theoricque des cieux*), followed by a treatise on an "equatorium" entitled *Pratique des mouvemens celestes*, with fourteen volvelles made with thirty-six moving parts (Bassantin 1557).

Peuerbach himself had probably felt that at least some of his readers might prefer a different kind of illustration. In the last manuscript of the *Theoricae novae* copied under his direction, shortly before his death, which he bequeathed to Bessarion in April 1461, the four initial figures of the first section are volvelles with graduated rotating disks, devised like "equatoria."[57] The Vitéz manuscript also has an original illustration: the diagrams in the text are less numerous than in the earlier manuscripts (and in the printed editions) and more synthetic, like in the *Theorica Gerardi* manuscripts; there are also new diagrams and the text is followed by an appendix of thirteen additional figures on the latitude and declination of planets, on parallaxes, on the eclipses, and on the methods of domification (Peuerbach 1455–1468, 18r–21r; Malpangotto 2012, 362–368). However, the early history of this manuscript is not well known, and the originality of its illustration could be attributed to Regiomontanus, to Bylica, or to Vitéz himself, as well as to Peuerbach.

At any rate, the printed tradition of the *Theoricae novae* was founded on the Regiomontanus edition, whose diagrams differed from those in the *Theorica Gerardi* as from those in the books on "equatoria;" the commentaries were meant to clarify the difficulties in the text and refine the geometrical analysis of the movements, not to construct instruments. However, Reinhold's *scholia* contain two diagrams called "Instruments" that correspond to folded plates where the moving parts of volvelles are drawn. The volvelles can be mounted in the book, on the diagram that represents the underlying fixed part of the instrument (Fig. 2.5), but this underlying diagram is also printed on a folded plate and the reader can construct a paper instrument separate from the book. As a large majority of the remaining copies has neither the mounted volvelles nor the folded plates, it is probable that the readers preferred the second method.[58] The first instrument enables one "to perceive clearly this variety of the Lunar motion" ("Instrumentum ex quo haec motus lunae varietas perspici potest") (Peuerbach 1542, G2v); the second one concerns the "proportion of the mouvement

[57] (Peuerbach 1461): "Theorica Solis" (1v); "Theorica Lunae" (4r); "Theorica trium superiorum et Veneris" (9v); "Theorica Mercurii." See also (Malpangotto 2012, Figs. 10–11).

[58] The folded plates contained the diagrams for both volvelles and three large figures that were to be inserted at the proper place in the book: the proportional minutes for the Moon ("Theorica minutorum proportionalium et diversitatis diametri Lunae"), the oval shape of the movement of the Moon ("Typus figurae ovalis seu potius lenticularis in Luna"), and the movement of Mercury ("Theorica omnem fere varietatem motus centri epicycli et apogii eccentrici Mercurii ostendens").

of the Sun and of the superior planets" ("Instrumentum proportionis motuum solis et superiorum planetarum") (Peuerbach 1542, K8v).

Let's take as an example the first instrument. It is described in the text, and the mounting instructions are on the plate with the moving parts (Fig. 2.6). In the

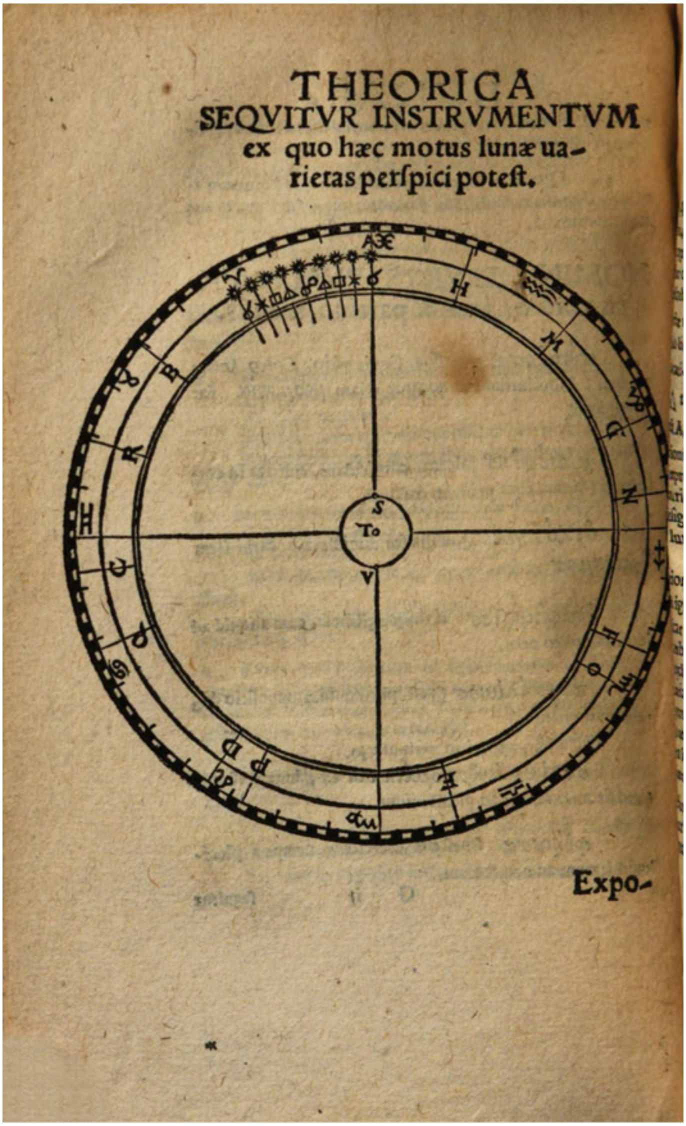

Fig. 2.5 The underlying diagram of the instrument for observing the relationship between the movement of the Sun and the movements of the Lunar orbs. Augsburg, Staats- und Stadtbibliothek. Math 745#. urn:nbn:de:bvb:12-bsb11267684-2. From (Peuerbach 1542, G2v)

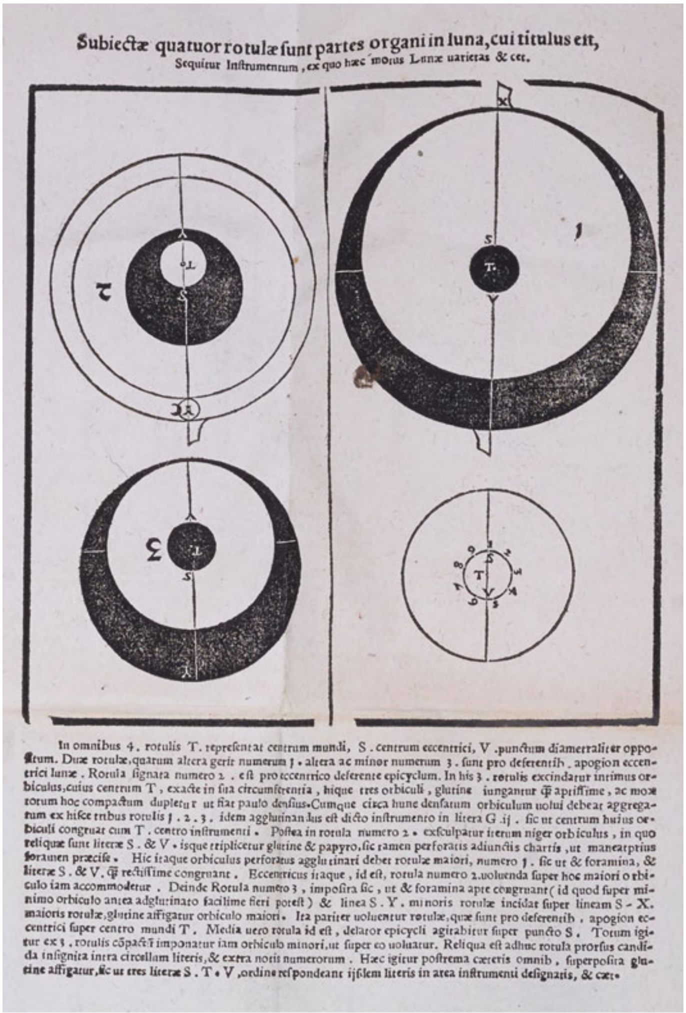

Fig. 2.6 The moving discs of the same instrument and the mounting instructions. Augsburg, Staats- und Stadtbibliothek. Math 745#. urn:nbn:de:bvb:12-bsb11267684-2. From (Peuerbach 1542, folded plate)

underlying diagram (Fig. 2.5) and on the four discs (*rotulae*) on the plate, T is the center of the world, S the center of the eccentric deferent, and V the "opposite point." Discs 1 and 3 represent the two "deformed" orbs, deferents of the apogee" that turn westward about the center of the world; disc 3 is the eccentric deferent between them, which turns eastward about its own center S.

First, the smaller circles at the center of discs 1, 2, and 3 must be carefully removed, glued together, and lined with paper or cardboard to increase the thickness. This thick small circle is glued at the center of the underlying diagram with exact superposition of the letters, to serve as a pivot around which all the discs will rotate. Then the small black circle inside disc 2 is removed and "tripled" (*triplicetur*) with glued paper, while taking care that the hole inside it remains precisely defined. This last circle is glued to disc 1, with the interior holes and the letters S and V superimposed exactly. Thus disc 2 (the eccentric) will be able to rotate around this "larger small circle" (*major orbiculus*) as around a second pivot. Then disc 3 is adjusted above disc 2 and glued on the "larger small circle," while taking care that line SY on disc 3 is exactly superimposed to line SX on disc one. Thus, each disc will rotate around its proper center.

Lastly, the small white disc with the figures is glued at the center of the instrument, while taking care that the letters STV are superimposed to those on the instrument, in the same order.

The underlying diagram (Fig. 2.5) that supports all the discs has an outward circle, the ecliptic, "divided into 180 small spaces ("spaciola"), each corresponding to two degrees. Next is the "circle where the Sun is carried" ("in quo sol vehitur"). For simplicity's sake, its center is T, as the Sun's eccentricity does not matter in this example where only the mean motions of the Sun and Moon are taken into account. Nine small Suns are drawn on it, to represent nine successive positions of the Sun in Aries during a Lunar month. Under each Sun is the symbol of an aspect: conjunction (under letter A), sextile (60°), square (90°), trine (120°), opposition (180°), second trine, second square, and so on; in brief the series of the aspects between the Sun and the Moon, from one conjunction, or new Moon, to the next.

In the mounted instrument, line TX ends in X, the apogee of the Lunar eccentric, while TY is the line of the mean motion of the Moon, and Y the center of the epicycle of the Moon. If we suppose that the first conjunction of the Sun and the Moon occurs at point A, the beginning of Aries, then X and Y will also be in A. Peuerbach explains, some pages before, that

> in every mean conjunction of the Sun and Moon, the center of the epicycle of the Moon, the line of mean motion of the Sun, and the apogee of the eccentric of the Moon are in one point of the zodiac. (Peuerbach 1987, 14)[59]

As the center of the epicycle moves eastward, in the order of the signs ("in consequentia"), while the apogee of the Lunar eccentric moves westward ("in antecedentia"), on the fourth day Y will be in B, and X in M, and the Sun will be midway between B and M, where is the symbol of the sextile aspect. According to Peurbach,

> The line of mean motion of the Sun is always in the middle, between the center of the epicycle of the moon and the apogee of its eccentric, appearing either with them or in the opposite position when both of them are together. (Peuerbach 1987, 14)[60]

Then the Moon, at its waxing crescent, will be in one of its "longitudines mediae," midway between the apogee and perigee of its eccentric.

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[59] (Peuerbach 1542, G1r): "… in omni media solis et lunae conjunctione, centrum epicycli lunae et linea medii motus solis et aux eccentrici lunae sint in uno puncto zodiaci."

[60] (Peuerbach 1542, G1r): "… semper linea medii motus solis sit in medio inter centrum epicycli lunae et augem eccentrici ejus, vel simul cum eis, vel in opposito amborum simul existentium."

Around the seventh day, Y is under C, and X is under N; the Moon, in dichotomy (in square aspect with the Sun) is at the perigee of its eccentric, and so on, until the end of the Lunar cycle. The reader, while rotating the discs according to the indications in the text (Peuerbach 1542, G3r–v), understands that the regularity of the phases masks a real "variety" in the Lunar movement that is composed of two contrary movements, made around two different centers, even in this simplest example that does not take into account the rotation of the Moon in its epicycle.

This instrument, like the second instrument, is nothing more than a pedagogical toy, but it fulfills several functions. It helps the reader to recapitulate and memorize what has been taught before, to acclimate to viewing particular celestial motions and phenomena in relation to other movements, and to acquire an aptitude for "mechanical thinking" (Shank 2007)—a necessity when dealing with as complex a moving object as the heavens.

2.8 Conclusion

The images of the *Theoricae novae planetarum* are probably a privileged example in the history of scientific illustration, for they served a particularly large range of functions. They were mnemonic tools and visual glossaries, and an essential element in Peuerbach's pedagogical approach, which consisted in constructing each "theory" step by step. They had a documentary role, as they offered plausible representations of the celestial spheres; they could be used as proofs of the soundness of a "theory," or simply as diagrams that help one follow a geometrical demonstration. Some of them were small-scale models not designed to reconstruct actual mechanisms, astronomical clocks, or computational instruments, but rather to serve as tools to help the mind better grasp the complex combination of movements in what was called *machina mundi*—not yet but soon to become *systema mundi* (Lerner 2005).

On the one hand, the *Theoricae novae* were the end of a long tradition begun with Ptolemy's *Planetary hypotheses*; they were not to survive the "new astronomy" of the next century. On the other hand, as an illustrated pedagogical and scientific book, they represented a pioneering experiment at the dawn of the age of printing. Their figures did not fit exactly in either of the main categories of scientific images: pictures of natural things (mineral, vegetal, animal, or human), geometrical diagrams, representations of artifacts or plans for machines; but they borrowed something from all. Above all, these figures, and their power to exercise the mind, were well suited to the period in which Peuerbach's treatise was composed, edited, and enriched by commentaries—a period of reform, transition, discussion, and hesitation in astronomical thought. It was a period when more and more astronomers were then involved in imagining, drawing, and comparing hypothetical (though not necessarily unreal) models of planetary movements.

References

Primary Sources

Apian, Petrus. 1540. *Astronomicum Caesareum.* Ingolstadt: Peter Apian.

Bacon, Roger. 1913. *Opera hactenus inedita Rogeri Baconi. IV*, ed. Robert Steele. Oxford: Clarendon Press.

Bacon, Roger. 1909. *Un fragment inédit de l'Opus tertium de Roger Bacon*, ed. Pierre Duhem. Quaracchi: Collegium S. Bonaventura.

Bainbridge, John. 1620. *Procli Sphaera. Ptolemaei De hypothesibus planetarum liber singularis, nunc primum in lucem editus. Cui accessit ejusdem Ptolemaei Canon regnorum.* London: William Jones.

Bassantin, James. 1557. *Astronomique discours.* Lyons: Jean de Tournes.

Euclid. 1956. *The thirteen books of the elements*, Trans. and comment. Thomas L. Heath. New York: Dover.

Finé, Oronce. 1526. *Aequatorium planetarum unico instrumento comprehensum omnium antehac excogitatorum, et intellectu et usu facillimum.* Paris: Nicolas Savetier.

Gaurico, Luca, ed. 1531. *Spherae tractatus Ioannis de Sacro Busto…Ioannis Baptistae Capuani Sipontini expositio in sphaera & theoricis. Ioannis de Monte Regio disputationes contra theoricas Gerardi…Gerardi Cremonensis theoricae planetarum ueteres. Georgii Purbachii theoricae planetarum nouae. Alpetragii Arabi theorica planetarum nuperrime Latinis mandata literis a Calo Calonymos Hebreo Neapolitano, ubi nititur saluare apparentias in motibus planetarum absq[ue] eccentricis & epicyclis.* Venice: Luca Antonio Giunta. https://hdl.handle.net/21.11103/sphaera.100999.

Gerardus. 14th cent. *Theorica planetarum*, BNF, Ms Lat. 7413(1): 18v–25v.

Gerardus. 14th/15th cent. *Theorica planetarum*, BNF, Ms Lat. 7294: 7v–15r.

Gerardus. 1472a. *Theorica planetarum.* Ferrara: Andrea Belfortis. https://hdl.handle.net/21.11103/sphaera.101681

Gerardus. 1472b. *Theorica planetarum.* Venice: Florentius de Argentina. https://hdl.handle.net/21.11103/sphaera.101682

Gerardus. 1478a. *Theorica planetarum.* Venice: Franciscus Renner. https://hdl.handle.net/21.11103/sphaera.100686

Gerardus. 1478b. *Theorica planetarum.* Venice: Adam von Rottweil. https://hdl.handle.net/21.11103/sphaera.101683

Gerardus. 1480. *Theorica planetarum.* Bologna: Fuscus. https://hdl.handle.net/21.11103/sphaera.100264

Gerardus. 1942. *Theorica planetarum Gerardi*, ed. Francis James Carmody. Berkeley: University of California.

Gerardus. 1974. *Theorica planetarum.* Trans. Olaf Pedersen. In *A source book in Medieval Science*, ed. Grant, Edward, 451–464. Cambridge: Harvard University Press.

Nuciarelli, Girolamo de, ed. 1518 (30 June). *Sphera mundi recognita, cum commentariis et authoribus in hoc volumine contentis, videlicet: Cichi Esculani cum textu…Theorica planetarum Joannis Cremonensis plurimum faciens ad disputationem Joannis de Monte Regio, quam in aliis impressis non reperies.* Venice: Luca Antonio Giunta. https://hdl.handle.net/21.11103/sphaera.100047.

Nuciarelli, Girolamo de, ed. 1518/1519 (19 January 1518 Venetian style = 1519). *Sphera cum commentis in hoc volumine contentis, videlicet. Cichi Esculani cum textu…Disputatio Johannis de Monte Regio: Textus Theorice cum expositione Joannis Baptiste Capuani: Ptolomeus de Speculis.* Venice: B. Locatelli for the heirs of Ottaviano Scoto. https://hdl.handle.net/21.11103/sphaera.101057.

Peuerbach, Georg von. 1454. *Incipit Theorica nova realem sperarum habitudinem atque motum cum terminis tabularum declarans.* Wien, Österreichische Nationalbibliothek, Cod. 5203, 2r–24r.

Peuerbach, Georg von. 1455–1468. *Incipit Theorica nova realem sperarum habitudinem atque motum cum terminis tabularum declarans*. Cracow, Biblioteka Jagiellońska, BJ 599.
Peuerbach, Georg von. 1461. *Theorica nova tabularum terminos motuumque habitudines explanans*. Rimini, Biblioteca Civica Gambalunga, Sc-Ms 27, 1–30.
Peuerbach, Georg von. ca. 1473. *Theoricae novae planetarum*. Nuremberg: Regiomontanus. https://hdl.handle.net/21.11103/sphaera.101610
Peuerbach, Georg von. 1482. *Theoricae novae planetarum*. [With Johannes de Sacro Bosco, *Sphaera mundi*; Regiomontanus: *Disputationes contra Cremonensia deliramenta*]. Venice: Erhard Ratdolt. https://hdl.handle.net/21.11103/sphaera.100692.
Peuerbach, Georg von. 1485. *Theoricae novae planetarum*. [With Johannes de Sacro Bosco, *Sphaera mundi*; Regiomontanus: *Disputationes contra Cremonensia deliramenta*]. Venice: Erhard Ratdolt. https://hdl.handle.net/21.11103/sphaera.101123.
Peuerbach, Georg von. 1488. *Theoricae novae planetarum*. [With Johannes de Sacro Bosco, *Sphaera mundi*; Regiomontanus: *Disputationes contra Cremonensia deliramenta*]. Venice: Johannes Lucilius Santritter. https://hdl.handle.net/21.11103/sphaera.100822.
Peuerbach, Georg von. 1495. *Theoricae novae planetarum*, comm. Franciscus Capuanus de Manfredonia. Venice: Simon Bevilaqua. https://hdl.handle.net/21.11103/sphaera.101636
Peuerbach, Georg von. 1525. *Theoricae novae planetarum*, ed. Oronce Finé. Paris: Regnault Chaudière. https://hdl.handle.net/21.11103/sphaera.101614
Peuerbach, Georg von. 1528. *Theoricae novae planetarum*, ed. Petrus Apianus. Ingoldstadt: Petrus Apianus. https://hdl.handle.net/21.11103/sphaera.101616
Peuerbach, Georg von. 1534. *Theoricae novae planetarum*, ed. Oronce Finé. Paris: Regnault Chaudière. https://hdl.handle.net/21.11103/sphaera.101615
Peuerbach, Georg von. 1535. *Theoricae novae planetarum*, ed. Jacob Milich. Wittenberg: Joseph Klug. https://hdl.handle.net/21.11103/sphaera.101618
Peuerbach, Georg von. 1542. *Theoricae novae planetarum*, comment. Erasmus Reinhold. Wittenberg: Johannes Lufft. https://hdl.handle.net/21.11103/sphaera.101637
Peuerbach, Georg von. 1553a. *Theoricae novae planetarum*, comment. Erasmus Reinhold. Paris: Charles Périer. https://hdl.handle.net/21.11103/sphaera.101638
Peuerbach, Georg von. 1553b. *Theoricae novae planetarum*, comment. Erasmus Reinhold (augmented). Wittenberg: Johannes Lufft. https://hdl.handle.net/21.11103/sphaera.101646
Peuerbach, Georg von. 1556. *Theoricae novae planetarum*, comment. Erasmus Reinhold (augmented). Paris: Charles Périer. https://hdl.handle.net/21.11103/sphaera.101649
Peuerbach, Georg von. 1987. *Theoricae novae planetarum*, trans. and comment. E.J. Aiton. *Osiris* 2nd ser. 3: 4–43.
Prierias, Sylvester, or Silvestro Mazzolini de Prierio. 1514. *In Spheram ac Theoricas preclarissima commentaria*. Milan: Gottardo da Ponte.
Regiomontanus, Johannes. 1972. *Joannis Regiomontani Opera collectanea* [a collection of facsimiles of early editions], ed. Felix Schmeidler. Osnabrück: Otto Zeller Verlag.
Reisch, Gregor. 1503. *Margarita philosophica*. Freiburg: Johann Schott.
Sarzosus, Franciscus. 1526. *In aequatorem planetarum libri duo*. Paris: Colines.
Schöner, Johann. 1521. *Aequatorium astronomicum*. Bamberg: Johann Schöner.
Schöner, Johann. 1522. *Equatorii astronomici omnium ferme uranicarum theorematum explanatorii canones*. Nuremberg: Friedrich Peypus.
Schöner, Johann. 1524. *Tabulae radicum extractarum ad fines annorum conscriptorum cum demonstrationibus exemplaribus pro motibus planetarum ex equatorio aucupandis*. Kirchehrenbach: Johann Schöner.

Secondary Literature

Aiton, E.J. 1981. Celestial spheres and circles. *History of Science* 19: 75–114.
Baldi, Bernardino. 1707. *Cronaca de Matematici*. Urbino: Angelo Antonio Monticelli.

Benjamin, Francis S., and G.J. Toomer. 1971. *Campanus of Novara and medieval planetary theory*. Madison: University of Wisconsin Press.
Bianchi, Massimo, and Marta Fattori. 1986. *Phantasia imaginatio: V Colloquio internazionale Roma 9–11 gennaio 1986*. Rome: Edizioni dell'Ateneo.
Birkenmajer, Ludwik Antoni. 1893. Marcin Bylica z Olkusza oraz narzędzia astronomiczne które zapisał Uniwersytetowi Jagiellońskiemu w roku 1493. *Rozprawy Akademii Umiejetnosci w Krakowie, Wydzial Matematyczno-Przyrodniczy, Ser. 2* 5: 1–164.
Brosseder, Claudia. 2004. *Im Bann der Sterne. Caspar Peucer, Philipp Melanchthon und andere Wittenbergen Astrologen*. Berlin: Akademie Verlag.
Brosseder, Claudia. 2005. The writing in the Wittenberg sky: Astrology in sixteenth-century Germany. *Journal of the History of Ideas* 66 (4): 557–576.
Byrne, James Steven. 2011. The mean distances of the sun and commentaries on the *Theorica planetarum. Journal for the History of Astronomy* 42: 205–221.
Cappelli, Adriano. 1983. *Cronologia, cronografia e calendario perpetuo*. Milan: Hoepli.
Caroti, Stefano. 1986. Melanchthon's astrology. In *'Astrologi hallucinati.' Stars and the end of the world in Luther's time*, ed. Paola Zambelli, 109–121. Berlin: Walter de Gruyter.
Chabás, José. 2012. Characteristics and typologies of medieval astronomical tables. *Journal for the History of Astronomy* 43: 269–286.
Chabás, José, and Bernard R. Goldstein. 2003. *The Alfonsine tables of Toledo*. Dordrecht: Springer.
Chabás, José and Bernard R. Goldstein. 2012. *A survey of European astronomical tables in the late Middle Ages*. Leiden: Brill.
Duhem, Pierre. 1969. *To save the phenomena. An essay on the idea of physical theory from Plato to Galileo*, Trans. Edmund Dolan and Chaminah Maschler. Chicago: University of Chicago Press.
Evans, James. 2003. The origins of Ptolemy's cosmos. In *Cosmology through time. Ancient and modern cosmologies in the Mediterranean area*, ed. Sergio Colafrancesco and Giuliana Giobbi, 123–132. Milan: Mimesis.
Evans, James, and Christian Carlos Carman. 2014. Mechanical astronomy: A route to the ancient discovery of epicycles and eccentrics. In *From Alexandria through Baghdad: Surveys and studies in the ancient Greek and medieval Islamic mathematical sciences in honor of J.L. Berggren*, ed. Nathan Sidoli and Glen Van Brummelen, 145–174. New York: Springer.
Federici-Vescovini, Graziella. 1996. Michel Scot et la *Theorica Planetarum Gerardi. Early Science and Medicine* 1 (2): 272–282.
Federici-Vescovini, Graziella. 1998. Autour de la *Theorica planetarum Gerardi*. In *Du copiste au collectionneur. Mélanges d'histoire des textes et des bibliothèques en l'honneur d'André Vernet*, ed. Anne-Marie Chagny-Sève and Geneviève Hasenohr, 169–174. Turhout: Brepols.
Field, Richard. 1965. *Fifteenth century woodcuts and metalcuts*. Washington: National Gallery of Art.
Goldstein, Bernard R. 1967. The Arabic version of Ptolemy's *Planetary hypotheses. Transactions of the American Philosophical Society* 57 (4): 3–55.
Grössing, Helmuth. 1983. *Humanistische Naturwissenschaft. Zur Geschichte der Wiener mathematischen Schulen des 15. und 16. Jahrhunderts*. Baden-Baden: Koerner.
Hamm, Elizabeth. 2016. Modeling the heavens: *Sphairopoiia* and Ptolemy's *Planetary Hypotheses. Perspectives on Science* 24: 416–424.
Hartner, Willy. 1968. Medieval views on cosmic dimensions and Ptolemy's Kitāb al-Manshūrāt. In *Oriens-Occidens. Ausgewählte Schriften zur Wissenschafts- und Kulturgeschichte. Festschrift zum 60. Geburtstag,* ed. W. Hartner, 319–348. Hildesheim: Olms.
Hugonnard-Roche, Henri. 1996. The influence of Arabic astronomy in the medieval West. In *Encyclopedia of the history of Arabic science*, vol. 1, ed. Roshdi Rashed and Régis. Morelon, 284–305. London and New York: Routledge.
Kren, Claudia. 1968. Homocentric astronomy in the Latin West. The *De reprobatione ecentricorum et epiciclorum* of Henry of Hesse. *Isis* 59: 269–281.
Kusukawa, Sachiko. 1995. *The transformation of natural philosophy: The case of Philip Melancthon*. Cambridge: Cambridge University Press.

Lagerlund, Henrik. 2007. *Representation and objects of thought in medieval philosophy*. Aldershot: Ashgate.

Langermann, Y. Tzvi. 1990. *Ibn al-Haytham's On the configuration of the world*. New York: Garland Publishing.

Lerner, Michel Pierre. 1996. *Le Monde des sphères I. Genèse et triomphe d'une représentation cosmique*. Paris: Les Belles Lettres.

Lerner, Michel Pierre. 2005. The origin and meaning of "world system." *Journal for the History of Astronomy* 36: 407–441.

Malpangotto, Michela. 2012. Les premiers manuscrits des *Theoricae novae planetarum* de Georg Peurbach: Présentation, description, évolution d'un ouvrage. *Revue d'histoire des sciences* 65 (2): 339–380.

Mancha, José Luis. 1990. La version alfonsi del 'Fi hayʾaẗ al-ʿālam' (*De configuratione mundi*) de Ibn al-Haytam (Oxford, Canon misc. 45, ff. 1r–56r). In *Ochava espera y astrofísica: Textos y estudios sobre las fuentes Árabes de la astronomía de Alfonso X*, ed. Mercè Comes, Honorino Mielgo, and Julio Samsó, 133–207. Barcelona: Instituto Millás Vallicrosa.

Murschel, Andrea. 1995. The structure and function of Ptolemy's physical hypotheses of planetary motions. *Journal for the History of Astronomy* 26: 33–61.

Müller, Kathrin. 2008. *Visuelle Weltaneignung: astronomische und kosmologische Diagramme in Handschriften des Mittelalters*. Göttingen: Vandenhoeck & Ruprecht.

Nutton, Vivian. 2001. Representation and memory in Renaissance anatomical illustration. In *Immagini per conoscere dal Rinascimento alla rivoluzione scientifica*, ed. Fabrizio Meroi and Claudio Pogliano, 61–80. Florence: Olschki.

Panaccio, Claude. 2010. Mental representation. In *The Cambridge history of medieval philosophy*, ed. Robert Pasnau, 357–368. Cambridge: Cambridge University Press.

Pantin, Isabelle. 1995. *La poésie du ciel en France dans la seconde moitié du seizième siècle*. Geneva: Droz.

Pantin, Isabelle. 2012. The first phases of the *Theoricæ planetarum* printed tradition (1474–1535): The evolution of a genre observed through its images. *Journal for the History of Astronomy* 43: 3–26.

Pantin, Isabelle. 2013. Analogy and difference: A comparative study of medical and astronomical images in books, 1470–1550. *Early Science and Medicine* 18: 9–44.

Pedersen, Fritz Saaby. 2002. *The Toledan tables: A review of the manuscripts and the textual versions with an edition*. Copenhagen: Kongelige Danske Videnskabernes Selskab.

Pedersen, Olaf. 1962. The *Theorica planetarum* literature of the Middle Ages. *Classica et mediaevalia* 23: 225–232.

Pedersen, Olaf. 1973. A fifteenth century glossary of astronomical terms. *Classica et mediaevalia Dissertationes* IX: 584–594.

Pedersen, Olaf. 1975. The *corpus astronomicum* and the traditions of medieval Latin astronomy: a tentative interpretation. In *Colloquia Copernicana III, astronomy of Copernicus and its background, Wroclaw*, 57–96. Warszawa, Krakow, Gdansk: Ossolineum (*Studia Copernicana*, XIII).

Pedersen, Olaf. 1978. The decline and fall of the *Theorica planetarum* literature: Renaissance astronomy and the art of printing. *Studia Copernicana* 16: 157–185.

Pedersen, Olaf. 1981. The origins of the *Theorica planetarum*. *Journal for the History of Astronomy* 12: 113–123.

Poulle, Emmanuel. 1980. *Les instruments de la théorie des planètes selon Ptolémée: équatoires et horlogerie planétaire du XIII^{e} au XVI^{e} siècle*. Geneva: Droz.

Poulle, Emmanuel. 1981. *Les sources astronomiques (textes, tables, instruments)*. Turnhout: Brepols.

Poulle, Emmanuel. 1984. *Les tables alphonsines avec les canons de Jean de Saxe*. Paris: CNRS.

Poulle, Emmanuel. 1987. Le vocabulaire de l'astronomie planétaire du XII^{e} au XIV^{e} siècle. In *La diffusione delle scienze islamiche nel medio evo europeo*, 193–212. Rome: Accademia nazionale dei Lincei.

Poulle, Emmanuel. 1988. The Alfonsine tables and Alfonso X of Castille. *Journal for the History of Astronomy* 29: 97–113.

Poulle, Emmanuel, and Denis Savoie. 1988. La survie de l'astronomie alphonsine. *Journal for the History of Astronomy* 29: 201–207.

Samsó, Julio. 1990. El original arabe y la version alfonsi del *Kitab Fi hayʾaẗ al-ʿālam* de Ibn al-Haytam. In *Ochava espera y astrofísica: Textos y estudios sobre las fuentes Árabes de la astronomía de Alfonso X*, ed. Mercè Comes, Honorino Mielgo, and Julio Samsó, 115–131. Barcelona: Instituto Millás Vallicrosa.

Sander, Max. 1942. *Le Livre à figures italien depuis 1467 jusqu'à 1530*, 6 vol. Milan: Hoepli.

Schofield, Malcolm. 1992. Aristotle on imagination. In *Essays on Aristotle's* De Anima, ed. Martha C. Nussbaum and Amélie Oksenberg Rorty, 249–278. Oxford: Clarendon Press.

Shank, Michael H. 1998. Regiomontanus and homocentric astronomy. *Journal for the History of Astronomy* 29: 157–166.

Shank, Michael H. 2002. Regiomontanus on Ptolemy, physical orbs, and astronomical fictionalism: Goldsteinian themes in *The Defense of Theon Against George of Trebizond*. *Perspectives on Science* 10: 179–207.

Shank, Michael H. 2007. Mechanical thinking in European astronomy (thirteenth to fifteenth centuries). In *Mechanics and cosmology in the medieval and early modern period*, ed. Massimo Bucciantini, Michele Camerota, and Sophie Roux, 3–27. Florence: Olschki.

Shank, Michael H. 2012. The geometrical diagrams in Regiomontanus' edition of his own *Disputationes* (ca 1475): Background, production, and diffusion. *Journal for the History of Astronomy* 43: 27–55.

Spruit, Leen. 1994–1995. *Species intelligibilis: From perception to knowledge.* Leiden: Brill.

Stromer, Wolfgang von. 1980. *Hæc opera fient in oppido Nuremberga Germanie ductu Joannis de Monteregio.* Regiomontanus und Nürnberg 1471–1475. In *Regiomontanus Studien*, ed. Günter Hamann, 267–290. Vienna: Akademie der Wissenschaften.

Swerdlow, Noel Mark. 2004. Alphonsine tables of Toledo and later Alphonsine tables. *Journal for the History of Astronomy* 35: 479–484.

Sylla, Edith Dudley. 2017. The status of astronomy as a science in fifteenth-century Cracow: Ibn al-Haytham, Peurbach, and Copernicus. In *Before Copernicus. The cultures and contexts of scientific learning in the Fifteenth century*, ed. E. Jamil Ragep and Rivka Feldhay, 45–78. Montreal: McGill-Queen's University Press.

Tavuzzi, Michael. 1997. *The life and work of Silvestro Mazzolini da Prierio 1456–1527*. Durham NC: Duke University Press.

Woodward, David. 1987. Medieval *mappaemundi.* In *The history of cartography*, vol. 1, ed. J.B. Harley and David Woodward, 286–370. Chicago: Chicago University Press.

Zinner, Ernst. 1990. *Regiomontanus. His life and work*, transl. Ezra Brown. Amsterdam: North-Holland.

Isabelle Pantin is Emerita Professor at the Ecole Normale Supérieure (PSL University Paris), and member of the Institut d'Histoire Moderne et Contemporaine (IHMC, UMR 8066). Her research interests concern notably the circulation of knowledge in printed books in the early modern period, and scientific illustration.