Alexander Jones (New York)

Translating Greek Astronomy: Theon of Smyrna on the Apparent Motions of the Planets

1 Introduction

The primary aim of most modern translations of Greek astronomical texts is to make these texts "accessible" to modern readers; however, translators vary in their notions of what this goal amounts to, and consequently follow different practices in how they go about their task. The modern reader is separated from the reader that the ancient author had in mind, not just by the difference of language. First of all, he or she comes to the text with a profoundly different background of experience and knowledge, and this is true for the modern reader who is comparatively ignorant of astronomy but often still more so for the reader who knows the science from a modern perspective. Secondly, his or her purpose in reading the text will also be one that the author did not envision. Perhaps the closest that a modern reader of a Greek astronomical text can get to impersonating the reader its author had in mind is in the case of Ptolemy's *Almagest* – a systematic empirical and mathematical deduction of models for the motions and phenomena of the heavenly bodies – when Ptolemy is regarded as a participant in a quasi-timeless dialogue of canonical classics.[1] More generally, one may address an ancient text from a historian's stance, seeking to extract from it information about the theories and practices of its own time and their relation to earlier stages of the science concerning which the author likely had limited interest and knowledge, and to later stages that the author could not foresee. In the present chapter, I assume that the reader comes with this historically-minded motivation, and the approach to translation that I will illustrate seeks to nudge him or her away from thinking of the text merely as a passive repository of such information, and towards understanding it as an artifact

1 The *Almagest* was included in the Utopian *Great Books of the Western World* (first published in 1952), which had wide influence in American liberal arts programs; it is still a core text in the mathematics curriculum of St. John's College (Annapolis and Santa Fe) and St. Mary's College of California.

whose purpose and expression also deserve study for the light they cast on the cultural and intellectual milieu of which it was a product.

A translator has to decide in what respects and to what degree the translation should make aspects of the text *immediately* comprehensible to the modern reader, because the means of doing this often involve introducing expressions and terminology that have a more exclusively technical character than their Greek counterparts had,[2] that were introduced in later periods, or that even conflict with the meaning of the Greek. A conscientious translator will often draw attention to these problems in notes or, in the case of frequently used terminology, in an introduction.[3] Unavoidably, however, such a translation is a significantly different text in more respects than language from what the author wrote and what an ancient reader would have read.

In the present article I attempt a translation that adheres almost as closely as possible to the literal and nontechnical meaning of the Greek, with the aim of bringing the reader closer to the kind of confrontation with the text that an ancient reader would have experienced. I am aware that a translation is not a time-machine and that it cannot erase the accumulation of 21st century experience from the reader's mind and substitute for it a simulated Greco-Roman upbringing. A maxim attributed to the musicologist Hans Keller comes to mind, that it is all very well to perform early music with "original instruments"; the trouble is that we do not have original ears! Moreover, choosing a nontechnical over a technical rendering of a Greek word that has both kinds of reference is not a neutral policy since it introduces an element of strangeness that the ancient reader presumably did not feel. My ideal reader will not approach the translation naively in the expectation that he or she will effortlessly be affected by the text just as an ancient reader would, but will be alert to the strangenesses and use them as a stimulus to the historical imagination.

It would seem especially appropriate to experiment with this kind of translation on a text that lies on the borderline where common language becomes technical language, and in particular one whose readers were expected to learn the specialized language as well as the content of the subject from the book itself, since in such a work astronomical terms and expressions would on first

2 The extent to which this occurs depends on what modern language one is translating into. English and French tend to employ derivatives from Latin or Greek to represent technical senses (e.g. "longitude" and "latitude" in contrast to "length" and "breadth" as renderings of μῆκος and πλάτος), whereas German tends to use native words for both common and technical senses (e.g. "Länge" and "Breite").

3 An outstanding model of moderately and conscientiously modernizing translation is G. J. Toomer's translation of Ptolemy's *Almagest* (Toomer [1984]).

encounter have called up their literal or nontechnical meanings in the original reader's mind. The astronomical section of Theon of Smyrna's *The Mathematics Useful for Reading Plato* offers itself as an attractive candidate. Theon was probably a somewhat older contemporary of Ptolemy, and belonged to and wrote for a Middle Platonist milieu that held many of the same intellectual stances that Ptolemy expected in his readers – though Theon wrote for beginners, whereas it is doubtful whether, had he known him, Ptolemy would have counted Theon himself among his ideal readership of people "who have already advanced to some degree" (οἱ ἤδη καὶ ἐπὶ ποσὸν προκεκοφότες, *Almagest* 1.1). The particular passage I have chosen contains within a brief span specimens of explanation, definition, mathematical argument, and quasi-historical narrative, and requires only a comparatively brief summary of the preceding matters in order to be understood.

2 The author

In the manuscripts of his one extant composition, *The Mathematics Useful for Reading Plato*, Theon is named as Θέων Σμυρναῖος, "Theon of Smyrna", or Θέων Σμυρναῖος Πλατωνικός, "Theon of Smyrna, Platonist". We also have reports of other writings by Theon, all devoted to Platonic topics. In a passage of the extant work (H146.3–5) he refers to a commentary that he has previously written on Plato's *Republic*, along with some sort of mechanical model (σφαιροποιία) of the "spindle and whorls" planetary system of the Myth of Er in *Republic* 10.[4] A book "on the order in which one should read Plato's works and on their titles" was known in Arabic according to Ibn al-Nadīm, which may have been the same as a work that Proklos and Ibn al-Qifti both refer to without title, containing genealogical and biographical information about Plato.[5]

Beyond the foregoing, textual sources offer us no evidence for Theon's biography beyond bracketing his career between the middle of the first century AD and the middle of the fifth, since among the earlier authors whom Theon cites, the latest securely datable one is Thrasyllos (died AD 36), the astrologer and

4 Citations of the text of Theon are by the page number and (where more precision is necessary) line number in Hiller (1878); thus, "H177.13" means Hiller's page 177, line 13.

5 Lippert (1894): 45–50. Al-Nadīm, *Fihrist* (tr. Dodge [1970]: 2.592–594); Proklos, *Commentary on Plato's Timaeus* (ed. Diehl [1903–1906]:1.82); Ibn al-Qifti, *Ta'rīḫ al-ḥukamā'* (ed Lippert [1894]: 17–27; Tarrant [1993]: 58–68). As Lippert proposed, the biographical information might have been in the book on the order and titles of Plato's works.

Platonist of the reign of Tiberius,[6] whereas there is no definite mention of Theon himself in later texts before Proklos (died AD 485). However, a Hadrianic bust of a philosopher bought in Smyrna by the Marseille merchant Anthoine Fouquier, who was French consul at Smyrna in 1669–1672, and now in the Capitoline Museum, bears the inscription Θέωνα Πλατωνικὸν φιλόσοφον ὁ ἱερεὺς Θέων τὸν πατέρα, "The priest Theon (has dedicated this portrait of) his father Theon the Platonist philosopher", and this Theon the Platonist Philosopher is most likely our author[7] – a rare instance of a contemporary, and likely realistic, portrait of an author whose writings have come down to us.[8] Starting already with Ismael Boulliau,[9] he has also frequently been identified with a certain Theon the Mathematician (ὁ μαθηματικός) whom Ptolemy records as having personally provided him with reports of his observations of Mercury and Venus,[10] out of which Ptolemy cites four observations made during AD 127–132; but this is exceedingly unlikely, since Theon of Smyrna was no practicing astronomer, but, as we shall see, derived the bulk of his information on the subject from second-hand authorities such as the Peripatetic Adrastos (active somewhere between the late second century BC and the early second century AD).[11]

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6 Theon's citations of Adrastos are often adduced to show that he must have written later than Adrastos's presumed *floruit*, typically given as c. AD 100 or thereabouts, but since Adrastos has in turn been dated by assigning him to the latest period consistent with his having written earlier than Theon, the argument is perfectly circular. The only solid *terminus post quem* for Adrastos is the presence among the astronomical discussions Theon credits to him of material derived from Hipparchos's solar theory (dating from about the third quarter of the second century BC); there is no reason to assume that Theon's citations of Thrasyllos (first half of the first century AD) were by way of Adrastos.

7 First suggested by Spon ([1679]: 135–136).

8 Richter (1965): 3.285. Bowen ([2002]: 312 n. 12) expresses scepticism (without saying why) of the stylistic dating of the bust. In fact there are convincing criteria for placing it within the first half of the second century AD: its blank, undrilled eyes would be very unlikely in a portrait later than the 140s, while the detailed treatment of hair and beard rule out pre-Antonine work (Smith [1998]: 62 and 83).

9 Boulliau (1644): 8.

10 Almagest 10.1: ἐν… ταῖς παρὰ Θέωνος τοῦ μαθηματικοῦ δοθείσαις ἡμῖν (*scil.* τηρήσεσιν).

11 Despite Martin's sharp objections (Martin [1849]: 8–10) and Toomer's understated protest (Toomer [1984]: 456 n. 83), "the identification is highly uncertain") Ptolemy's acquaintance continues to be uncritically equated with Theon of Smyrna; see e.g. the articles on Theon in *Encyclopedia of Ancient History* (Bernard [2013]), *Biographical Encyclopedia of Astronomers* (Hatch [2014]), and *Brill's New Pauly* (Folkerts [2011]). It should be enough to point out (1) that Theon of Smyrna's discussion of the planets assumes that simple epicyclic models suffice to explain their apparent motion, (2) that in passages a few pages apart (H175.14–15 and 190.9–191.3) he specifies opposite directions for the revolution of a planet around the epicycle, and (3)

3 The work

Theon's *The Mathematics Useful for Reading Plato*, as it is presented in the two most recent editions by Eduard Hiller (1878) and Jean Dupuis (1892), is a union of two non-overlapping texts, each of which is preserved by way of a single extant medieval Greek manuscript.[12] *Marc. gr.* 307, a twelfth century codex, contains a text bearing the title Θέωνος Σμυρναίου Πλατωνικοῦ τῶν κατὰ τὸ μαθηματικὸν χρησίμων εἰς τὴν Πλάτωνος ἀνάγνωσιν, "(The book) of Theon of Smyrna the Platonist of the things useful with respect to mathematics for the reading of Plato"; the title is repeated at the end with the additional remark "end, with God, of the present book". The last sentences of the text itself, however, indicate that there ought to be a continuation:

> "These are the most necessary among the most useful things in the aforesaid mathematical subjects (ἐν τοῖς προειρημένοις μαθήμασιν), as in a summary reporting, for the reading of the Platonic (*scil.* writings). It remains to recount in an elementary manner also the things in astronomy." (H119.17–21)

On the other hand, the fourteenth century codex *Marc. gr.* 303 contains an assemblage of mathematical, astronomical, and astrological texts, among which is one entitled Θέωνος Σμυρναίου τῶν εἰς τὸ μαθηματικὸν χρησίμων, "(The book) of Theon of Smyrna of the things useful for mathematics", which begins as follows:

> "That the whole cosmos is spherical, and the Earth is at its center, being itself sphere-shaped too, and having the relation of a center with respect to position and a point with respect to size relative to the whole, it is necessary to establish before the rest. For the more precise expounding of these things requires more extended examination, as (also?) many words. But it will suffice, for the general view of the things that are going to be reported, to recount just the things that are reported summarily by Adrastos." (H120.1–9)

that he believes (H190.13–191.3) that a planet's stationary points occur when it is at its greatest elongation from the center of its epicycle (which would only be correct if the epicycle was standing still instead of revolving around the Earth). It is inconceivable that a competent astronomer of the first half of the second century AD could have been ignorant of the zodiacal anomaly or of the conditions determining the stationary points and retrogradations in an epicyclic model.

12 According to Hiller (1878): v–vii, other manuscripts containing the same texts are descendants of one or the other of this pair of manuscripts. On the other hand, an extended excerpt concerning harmonics and some verses on the planets ascribed to Alexander of Aitolia are transmitted separately in manuscripts that Hiller believed to descend from lost exemplars from earlier in the text's tradition.

This text, which is entirely on astronomical topics, has enough links to the text in *Marc. gr.* 307 to convince one that it is another part of the same work, and it follows well as the immediate continuation of the text in the other manuscript.[13] Its end is marked with a curt colophon τέλος ("end"), but again the last sentences imply that more should follow:

> "Up to this point, the most necessary and most important things from astronomy (ἐξ ἀστρολογίας) for the reading of the Platonic (writings). But since we said that there exists a music and harmony in instruments, and one in numbers, and one in cosmos, and we promised next all the necessary things concerning the (music and harmony) in cosmos after the reporting concerning astronomy – for Plato too said that it is fifth among the mathematical subjects after numerics (ἀριθμητική), geometry, stereometry, astronomy (ἀστρονομία) – one ought to point out also the things that Thrasyllos points out besides concerning these things summarily together with the things that we ourselves have previously worked out."

This promise of a section dealing with cosmic harmony does indeed appear twice in the text in *Marc. gr.* 307 (H47.8–17 and H93.9–11), which also make it clear that this was to be the concluding section of the book. So it would appear that at some stage in the book's earlier transmission, the text was physically divided into three portions though initially (to judge from the survival of the transitional passages) with the intention that they should still be regarded as a single composition.

It is disputable whether, even with the lost section on cosmic harmonies, we would possess the whole work that Theon originally produced. Right at the beginning (H1.13–2.2), Theon expresses the intention of providing the reader with relevant material from numerics, music, geometry, stereometry (i.e. solid geometry), and astronomy, whereas the work as we have it proceeds (in *Marc. gr.* 307) from numerics to harmonics to proportionality and means (which could be considered an extension of harmonics) to astronomy, passing over geometry and stereometry. Either Theon never got around to composing the sections on these topics, or they have dropped out in the course of the book's transmission.[14] In the latter case, it would have been a separate event from the one that split the sections on astronomy and cosmic harmonies from the first portion of the book, since the transitional passages leading into these sections are in both

13 However, following a suggestion of Hiller (1878): 120 app., I suspect that the first sentence is an interpolation intended to give the text a self-standing beginning.

14 Tannery (1894): 146, would have it that Theon considered his presentation of planar and solid figurate numbers (H26.5–45.8) to satisfy his promise to treat geometry and stereometry.

cases preserved at the ends of the preceding sections in the manuscript tradition.

While we thus do not possess the entire book that Theon wrote (or at least, that he meant to write), what we have provides a clear sense of his purpose, intended readership, and methods. It is a book directed at students of philosophy who have not had the benefit of thorough mathematical education beginning in childhood,[15] aiming to provide them with an adequate background in just those parts of certain divisions of mathematics that a reader of the Platonic dialogues ought to know. It is thus not a systematic introduction to methods and concepts in any of the fields that it covers. Theon asserts (H16.17–21) that it would be best if his reader has already progressed at least through "the first geometrical elements" (διὰ γοῦν τῆς πρώτης γραμμικῆς στοιχειώσεως κεχωρηκέναι), though he claims that even "someone completely uninitiated in mathematics" (τῷ παντάπασιν ἀμυήτῳ τῶν μαθημάτων) will be able to comprehend his book. In fact, some of the topics that he takes up, in particular those to do with number, are introduced at a rather elementary level, but the astronomical section presupposes a broad familiarity with geometry such as one would acquire through Euclid's *Elements*. Additionally, Theon – perhaps through inadvertence – employs without prior explanation a few astronomical conventions such as the division of the circle into 360 degrees.

In the sections on harmonics and astronomy, Theon tells the reader that he has taken a great part of his material from three earlier writers in the tradition of Platonist or Peripatetic commentators: Thrasyllos for harmonics; Derkyllides for astronomy, from a work or section of a work that Theon refers to as "on the spindle and the whorls that are spoken of in Plato's *Republic*";[16] and above all Adrastos of Aphrodisias the Peripatetic for both harmonics and astronomy, from his *Commentary on the Timaeus*.[17] His general practice is to specify his source by name at the beginning of a block of quoted or adapted text (e.g. H120.6–9 already quoted above, "it will suffice… to recount just the things that are reported summarily by Adrastos"). He may also end the block with a reminder of his source (e.g. H129.5–9, closing the block begun at H120.10, and followed immediately by a new block of Adrastean material ("In what follows next he says…").

15 Cf. H1.9–10: πανὺ πόλλου τοῦ ἐκ παίδων πόνου δεόμενον, "absolutely demanding much labor starting in childhood".

16 Simplikios, *Commentary on Aristotle's Physics*, *CAG* 9.247, cites by way of Porphyrios an eleventh book of a work by Derkyllides called "Plato's philosophy".

17 Theon calls him simply Adrastos, and does not identify the work. We owe its title to Porphyrios, *Commentary on Ptolemy's Harmonics* (ed. Düring [1930]: 96), who quotes from it a sentence that appears in Theon with only minor verbal differences at H50.22–51.4.

Intermittently within a block Theon inserts other reminders, which can be as brief as a parenthetic "he says".

None of Theon's principal source texts survive, though extensive passages in Calcidius's commentary on Plato's *Timaeus*, while not attributed by Calcidius to any source author, parallel Theon's adaptations from Adrastos. The verbal correspondence in these passages between Theon's Greek and Calcidius's Latin is so close – as is also the correspondence between their diagrams – that one must conclude either that Calcidius translated them from Theon's work or that both Theon and Calcidius were faithfully but separately reproducing Adrastos's wording.[18] What in my view is the decisive argument that Calcidius did not derive the passages in question from Theon's book is that the overlaps consist *only* of material that Theon unmistakably attributes to Adrastos or that from its connection with other material explicitly attributed to Adrastos seems likely also to be derived from him, whereas Theon's occasional interjections from his own part as well as the material he tells us comes from Thrasyllos and Derkyllides have no counterpart in Calcidius.[19] If this is correct, then Theon's reworking of Adrastos's text was mostly limited to abridgement or paraphrase. It is not possible to verify whether he treated his borrowings from Thrasyllos and Derkyllides in the same way; he does complain (H198.9–11) that Derkyllides followed no sensible sequence in presenting his astronomical material, so reordering at least seems plausible.[20]

Theon also intermittently cites authors who were actual practitioners of the mathematical sciences. Archimedes's name crops up only in connection with famous results: the approximate value of the ratio of a circle's circumference to its diameter (H124.12–15) and the ratio of a sphere's volume to that of the cylinder that contains it (H127.2–3). Similarly, Eratosthenes is mentioned for his value for the Earth's circumference and his estimate of the maximum difference in altitude between the highest and lowest points of the Earth's surface (H124.10–12), but elsewhere Theon frequently quotes or paraphrases from a book by Eratosthenes entitled Πλατωνικός, which seems to have been, like Theon's own book, a survey of mathematical topics related in various ways to Plato. The several citations of Hipparchos are all for results or summarized

18 For the hypothesis that Calcidius depended on Theon, see Martin (1849): 18–21; Bakhouche (2011): 1.36–38. Arguing for his direct dependence on Adrastos, Bergk (1850): 176; Hiller (1871); Waszink (1962): xxxv–xxxviii.

19 Hiller (1871): 584–585.

20 Bowen (2013) proposes that Theon's handling of material from Adrastos and Derkyllides was more "creative" than I have argued, while abstaining from expressing an opinion of the relation between Calcidius and Theon.

opinions, and it is probable that all of them came to Theon by way of either Adrastos or Derkyllides. It appears, therefore, that Theon relied mostly if not entirely on second-hand, philosophically oriented sources and had no significant engagement with the technical mathematical and scientific literature.

Theon does not explicitly list the specific works of Plato that his book will assist one to read. The dialogues that he makes reference to by title are the *Republic*, the *Timaeus*, the *Epinomis*, the *Phaedo*, and the *Philebus*, while there are more glancing allusions without title to the *Phaedrus* and the *Theaetetus*. This rather limited selection reflects the tendency of Middle Platonists to narrow their attention to a subset of the Platonic dialogues among which the *Republic* and *Timaeus* were especially prominent.

4 Editions and text

Three partial and two complete editions exist of Theon's book. Boulliau published in 1644 an edition with Latin translation of the first portion of the work from a manuscript in the library of Jacques Auguste de Thou, now *Par. gr.* 2014, a descendant of *Marc. gr.* 307.[21] While preparing his edition, Boulliau learned from Isaac Voss of the existence in the Biblioteca Ambrosiana of a manuscript of the astronomical section, but he never carried out his expressed intention of publishing it.[22] In 1827, Jan Jacob de Gelder published an edition just of the first sections, that is, the introduction and the section on numerics, revised from Boulliau's text and Latin translation with an apparatus based on collations of two manuscripts, *Scal. gr.* 50 and *Voss. gr. Q°* 54.[23] The astronomical part was finally edited with a Latin translation by Thomas H. Martin in 1849, from *Par. gr.* 1821, a descendant of *Marc. gr.* 303.

These partial texts were superseded by Hiller's 1878 Teubner edition, the first to reunite the surviving parts of Theon's book. Hiller identified the two Venice manuscripts *Marc. gr.* 303 and 307 as the archetypes of the tradition, and only cited other manuscripts intermittently and collectively (as "apogr.") as a

21 Boulliau (1644).
22 Boulliau (1644): 9. Boulliau did obtain access to a copy (now *Par. gr.* 1821) of the text in the library of Charles de Montchal, bishop of Toulouse, but only published very short extracts in 1644 and 1645; see Martin (1849): iii–iv, and p. 28–31, for the history of *Par. gr.* (1821). Note that Martin confuses Nicolas Foucquet, who at one time owned this manuscript, with Anthoine Fouquier who procured the bust of Theon.
23 De Gelder (1827).

source of conjectural readings. Unlike the earlier editors, he provided neither translation nor commentary, but his apparatus incorporates citations and parallels as well as brief notes and references to relevant scholarship.

The edition by Dupuis, which appeared not long after Hiller's, has a French translation and notes but no apparatus, though Dupuis reports where he adopts readings diverging from Hiller's.[24] More recently, a second annotated translation into French by Joëlle Delattre Biencourt, based primarily on Hiller's text while adopting some of Dupuis's readings, and an Italian translation with commentary by Federico M. Petrucci have appeared.[25] The only other complete translation into a modern language of which I am aware is an English rendering by Robert Lawlor and Deborah Lawlor based on Dupuis's French translation rather than on the Greek text.[26]

Several parts of Theon's book contain diagrams, with some of those in the astronomical section being fairly complex geometrical figures. Martin had to reconstruct the diagrams on the basis of the text, since the manuscript on which he depended omitted them.[27] Hiller reports that the diagrams in *Marc. gr.* 303 were executed very carelessly (*cum figuris neglegentissime factis*);[28] those that appear in his text have no apparatus, and it does not seem that in drawing them he paid much attention to the testimony of the manuscript. Dupuis, too, has nothing to say about his diagrams.

The manuscripts divide Theon's work into chapters with subject headings. Both Boulliau and Martin retained this division although Martin believed that it did not go back to the author since the chapter titles appeared not to reflect the contents adequately.[29] Being of the same view, Hiller relegated the chapter titles to his apparatus and presented an undivided text. Dupuis retains the chapter divisions while putting the titles in footnotes, and in addition divides the work into three major parts (he calls them μέρη or βιβλία) containing respectively the introduction and section on numerics, the section on music, and the section on astronomy.[30]

24 Dupuis (1892).

25 Delattre Biencourt (2010); Petrucci (2012).

26 Lawlor and Lawlor (1979).

27 Martin (1849): 37.

28 Hiller (1878): vi.

29 Martin (1849): 36. Martin attempted to discriminate between meaningful and "useless" chapter titles, and even inserted some on his own initiative.

30 Dupuis believed that Theon's work originally comprised five books corresponding to the five divisions of mathematics that Theon lists in his introduction; see Dupuis (1892): vi.

For the present translation I have followed Hiller's edition. The two diagrams are modelled, with corrections, on those in *Marc. gr.* 303, f. 13v; for details and comparison with Hiller's diagrams, see the Commentary. In the manuscript, the diagrams are drawn in the margins, in at best very rough proximity to the passages of text that refer to them. I have placed them immediately following the relevant text passages, following the customary practice of diagram placement in manuscripts of Greek mathematical and scientific texts.

5 The cosmological framework and the goal of astronomy[31]

Theon's cosmology owes something to Plato, something to Aristotle, and something again to more recent mathematical astronomers such as Hipparchos. From Plato's *Timaeus* (especially 32C–37C) comes the fundamental idea of a purposeful, divine, ensouled, and spherical geocentric cosmos, whose outermost part revolves daily with what Plato calls the "motion of the same", and the Sun, Moon, and planets are borne by this part while also revolving in the opposite direction with the slower and oblique "motion of the different". From Aristotle (especially *Physics*, *De Caelo*, and *Metaphysics* Λ) comes the conception of a spherical cosmos having two tiers distinguished by the kind of matter that they are made of. The region of the cosmos occupied by the Sun, Moon, planets, and stars, οὐρανός (conventionally "heavens" in English as distinct from the singular "heaven" of Christian theology), is composed of uniformly revolving spheres of the immutable "fifth body" (i.e. the fifth element after earth, water, air, and fire, usually called "ether"),[32] whereas the part of the cosmos enclosed by the heavens is a world that is, taken as a whole, stationary, and composed of the four mutable elements undergoing processes of continual change and interchange sustained by the revolutions of the heavenly spheres. Theon does not dwell on points of conflict between Aristotle and Plato, in particular concerning

31 Readers unfamiliar with Greek astronomical literature may wish to consult section 7 below for detailed discussion of some of the terminology arising in the present and following sections, especially in the quotations.

32 The existence of Aristotle's celestial fifth element was brought into doubt in the early post-Aristotle Peripatetic school, and forcefully rejected by the Peripatetic Xenarchos of Seleucia in the first century BC (Falcon [2012]). Theon, whose reference to "certain spheres… of the fifth body situated in the depth of the whole heavens" probably comes from Adrastos (the passage is paralleled in Calcidius), appears to be unaffected by these controversies.

whether the cosmos and time had a temporal beginning; he is typical of Middle and later Platonists in treating Aristotle as a gateway to his more enigmatic master. Quoting or paraphrasing Adrastos, he sums up this Platonic-Peripatetic *a priori* framework of his cosmology as follows (H148.13–149.6):

> "The whole cosmos... (is moved,) being borne with a travel that is circular and appropriate to the spherical shape, by the first (mover); whence it was also fashioned for the sake of the most excellent and best. But for the sake of the numbering of time[33] and the transformation of the things near the Earth and far from the Earth, the travel of the wandering (stars, i.e. the Sun, Moon, and planets) came to be; for the things here (below the heavens) also transform in all ways together with their (*scil.* the heavenly bodies') turnings (τροπαί, meaning their movements north and south) as they approach and recede. For the travel of the nonwandering (stars, i.e. fixed stars) is simple and one in a circle, orderly and uniform. But that of the things below the Moon and around us and extending to us (ourselves) is all transformation and motion and, as he (*scil.* Empedokles) says, "there is rancor and slaughter and hosts of other dooms"."

As he goes on to explain, the Sun, Moon, and planets keep the mundane elements from stratifying and settling into a stable condition through their complex motions, which are nevertheless composed of simple, uniform, circular revolutions.

Later Platonists would claim that Plato assigned to the astronomers the task of showing what uniform and regular motions had to be hypothesized so that "the appearances concerning the motions of the wandering (stars) would be saved".[34] Theon does not retail this story, but he repeatedly characterizes the goal of astronomical modelling as "saving the appearances" (σῴζειν τὰ φαινόμενα), by which he means demonstrating that a particular hypothesis would result in observable behaviour matching the appearances. Such a demonstration is necessary but not sufficient to establish the truth of a hypothesis, since more than one hypothesis may in fact turn out to "save" the same appearances. A valid hypothesis must be "according to nature" (κατὰ φύσιν), that is, it must explain the appearances as caused by bodies acting in accordance with the nature of the matter of which they are composed. For the etherial matter of the heavens, this means three-dimensional bodies delimited by spherical surfaces and moving with a simple, uniform circular revolution.

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33 Cf. Plato, *Timaeus* 38B–C.

34 Simplikios, *Commentary on Aristotle's De Caelo* (ed. Heiberg [1894]: 488), citing Sosigenes, with the Peripatetic Eudemos's *Astronomical History* as the alleged ultimate source. For the origins of this legend see Zhmud (1998).

These bodies and revolutions are not required to have the center of the Earth and cosmos as *their* center; in fact, Theon interprets both Plato and Aristotle as having posited spheres situated entirely up in the heavens and not enclosing the Earth.[35] The apparently irregular motions of the heavenly bodies are consequences not only of the fact that the bodies are undergoing a combination of revolutions simultaneously but also of the fact that the bodies have a motion "in depth", that is, their revolutions make them periodically move nearer to and further from the center of the cosmos so that we see their motions, in perspective, as speeding up and slowing down.

Theon describes two hypotheses that he says are advocated by the "mathematicians" (i.e. mathematical astronomers). In one, called "the hypothesis according to eccentric (circle)" (Fig. 1), the heavenly body (*P*) moves uniformly along a circular path that surrounds the center of the cosmos (*T*) but whose center is a different point (*C*) that either is stationary or travels uniformly along a smaller circle concentric with the cosmos.[36] In the other hypothesis "according to epicycle" (Fig. 2), the heavenly body (*P*) moves uniformly along a circular path called the "epicycle", which does not enclose the center of the cosmos (*T*), while the center of the epicycle (*E*) revolves uniformly along a circle that Theon calls the "concentric" (in the Middle Ages it came to be called the "deferent") because its center is the center of the cosmos. Theon believes that both the eccentric and the epicyclic hypotheses result in correct paths and speeds for the Sun, Moon, and planets, and consequently they "save the appearances"; but neither is a satisfactory hypothesis because they inappropriately situate the causes of the appearances in circular lines, not in three-dimensional material bodies. Theon's preferred hypothesis is a kind of fleshed-out, three-dimensional version of the epicyclic hypothesis (Fig. 3), in which the epicycle becomes a revolving solid sphere (*e*) with the visible Sun, Moon, or planet (*P*) embedded

35 Theon presents the "unwinding spheres" of Aristotle, *Metaphysics* Λ not as spherical shells concentric and coaxial with the planetary shells whose revolutions they "unwind", but as solid spheres lodged in the space between planetary shells and operating like gears to transfer motion from one shell to the next one inwards (H180.8–22), and he believes that Plato hinted at epicycles in the Myth of Er at the end of the *Republic* (H188.25–189.6). He does not in any case insist that either Plato's or Aristotle's understanding of astronomy was complete or entirely correct.

36 Theon illustrates the eccentric hypothesis with reference to the Sun and treating the eccenter's center as stationary (H155.1–158.9); but in a subsequent passage translated in this article (H172.22–174.15) he states that there is a small discrepancy in the periodicities of the Sun's apparent motion that would imply a (very slow) revolution of the center of its eccenter, just as in the case of the Moon and planets.

near its surface, and the deferent is replaced by a revolving spherical shell (*s*) whose thickness is just sufficient for the epicycle sphere to be embedded in it and carried by it around the center of the cosmos (*T*).

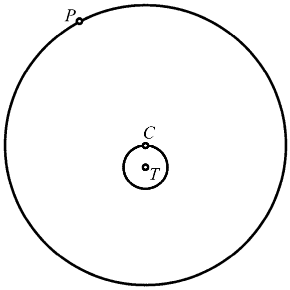


Fig. 1: Eccentric hypothesis

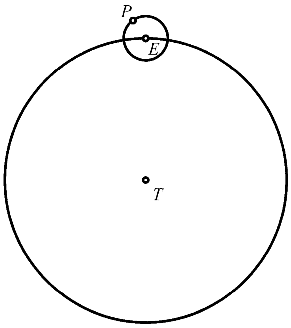


Fig. 2: Epicyclic hypothesis

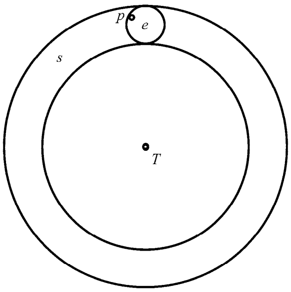


Fig. 3: Theon's solid body hypothesis

6 Context of the translated passage

The first parts of the astronomical section (H120–129) are, according to Theon, a summary presentation of Adrastos's arguments that the whole cosmos is spherical, that the Earth too is spherical, at the center of the cosmos, and pointlike in size relative to the cosmos. Continuing to identify Adrastos as his source, Theon next (H129–133) defines the principal celestial circles: the equator, the tropics, the arctic and antarctic circles,[37] the zodiacal circle, the horizon, and the meridian. The distinction is then (H134–135) delineated between the fixed stars and "Sun, Moon, and all the other stars which are called wanderers", i.e. the five planets, with an account of the planets' motion in "length" (i.e. celestial longitude) along the ecliptic circle and their oscillating motion in "breadth" (celestial latitude) and "depth" (distance from the center of the cosmos), which last is correlated with their apparently nonuniform rates of motion through the zodiacal signs. Theon gives ranges in degrees for each of the wanderers' deviation in breadth from the circle through the middles of the zodiacal signs (i.e. the ecliptic) and figures in days or years for their periods of revolution in length (H135–136). This is followed by a discussion of their synodic cycles (H136–138), and the order of their distances from the Earth, leading into an exposition of the *Republic*'s "spindle of necessity" (H138–147).

Saying that he his paraphrasing Adrastos, Theon now (H147–150) recounts how the Sun and Moon appear always to move eastwards along the zodiacal circle whereas the other "wanderers" appear to exhibit stationary points and reversals of direction; in general, according to Adrastos, the movement of the fixed stars is perfectly regular, whereas the "wanderers" seem to move cyclically but irregularly, thereby causing through their northward and southward oscillations and their approaches to and recessions from the Earth the continual processes of generation and corruption on the Earth.

At this point (H150–152), still saying repeatedly that he is following Adrastos, Theon turns to the topic of the "arrangement of the spheres or circles"

37 Theon's arctic and antarctic circles are not the celestial counterparts of the modern terrestrial circles bearing these names, but rather the circle bounding the stars of the observer's northern sky that never set below the horizon and the circle bounding the stars that never rise above the observer's southern horizon. These are defined as circles parallel to the equator and tangent to the observer's horizon at its northernmost and southernmost points, i.e. having a declination of $\pm(90°-\varphi)$ where φ is the observer's latitude.

of the seven planets that would "save the phenomena".[38] The conflict to be resolved is between the "physical and necessary" requirement that all the heavenly bodies must move "uniformly" (ὁμαλῶς) and "in an orderly manner" (εὐτάκτως) – terms that Adrastos defines respectively as traversing equal intervals (διαστήματα) in equal times and never stopping or changing direction – and the "apparition" (φαντασία) that all the planets seem (δοκεῖ) to move nonuniformly and some of them even in a "disorderly" manner. The Sun is chosen to serve as an example of how the apparent nonuniformity can result "by happenstance" from a motion that is in reality "simple" (ἁπλῆν).

The Sun (H152–154) is seen to traverse the four equal quadrants of the zodiac that begin with the first degrees of Aries, Libra, Capricorn, and Cancer in unequal times (respectively 94 1/2, 92 1/2, 88 1/8, and 90 1/8 days), whereas as a divine being it must in reality move uniformly and in an orderly manner on its own circle. Consequently, our standpoint, which is the center of the "whole" (i.e. of the cosmos), cannot be the center of the Sun's own circle, but must be another point either inside the Sun's circle or outside it.[39] Either situation, according to Adrastos, will save the phenomena. The "mathematicians", however, are in disagreement, some of them insisting that the planets move only on eccentric circles that have the center of the whole inside the circles, or only on "epicycles", that is, circles that do not enclose the center of the whole and whose centers revolve around the center of the whole along a circular path (see Figs. 1 and 2). This disagreement is pointless, because, as will be demonstrated later, the circles in question are all described by the planets "by happenstance", i.e. they are not in themselves realities but the consequences of realities.

Theon now (H155–158) gives a detailed geometrical discussion, attributed to Adrastos, of a configuration of an eccentric circular path for the Sun that would result in the nonuniformity implied by the inequality of the four seasons, following this with a more prolix discussion (H158–166) of a configuration involving an epicycle that the Sun revolves around while the epicycle revolves around the center of the whole. Citing Hipparchos as having said that it was a matter worthy of mathematical understanding to show the reason why two such widely differing hypotheses lead to the same appearances, Theon proceeds (H166–172) to give us Adrastos's demonstration of how an eccentric circle results by happenstance from an epicyclic hypothesis, and a demonstration (probably also

38 There is a defect in the text in *Marc. gr.* 303 in the introductory sentence of this passage, but the sense is clear.

39 The possibility of our occupying a point *on* the Sun's circle is easily excluded.

Adrastos's[40]) of how an epicycle results by happenstance from an eccentric hypothesis.

The passage translated below (H172–178) follows at this point; it concerns how the general conclusions concerning epicyclic and eccentric hypotheses arrived at in the preceding passages for the Sun can be applied, with suitable modifications, to the other planets. In the last part of this passage, after reminding us that he has been following Adrastos, Theon returns to the claim that the epicyclic and eccentric circles that he has been discussing are hypotheses of the mathematicians, lacking in physical explanations and therefore incomplete.

A brief summary will suffice for what follows after the translated passage. Theon proceeds by way of a short review of Aristotle's physical interpretation of the homocentric sphere models of Eudoxos and Kallippos (H178–180) to a physical system of solid spheres and spherical shells of etherial matter that he offers as the reality behind the epicyclic and eccentric hypotheses for the planets (H180–189). The Adrastean portion of Theon's astronomical section closes (H189–198) with explanations of various phenomena of the planets: planetary stations and retrogradations, occultations, and eclipses.

7 Terminological aspects of the translation

Theon's astronomical section contains terminology that raises many issues that have relevance for translating other works of Greek astronomical literature. In this section, I am primarily concerned with words and expressions that arise in the selection translated in this paper, but where appropriate I have situated these within a more general treatment of categories of terminology.

There exist no specialized lexicographical resources for Greek astronomical terminology, while the standard Liddell-Scott-Jones *Greek Lexicon* cannot always be counted to provide definitions that accurately reflect the usage of astronomical authors. Few of the central texts have received full-scale philological and technical commentaries, though annotated translations such as Gerald J. Toomer's of Ptolemy's *Almagest* and James Evans and J. Lennart Berggren's of Geminos's *Introduction to the Phenomena* are helpful guides.[41] Ultimately, our basis for recovering the specialized meanings of the terminology of Greek

40 See commentary to H172.15.

41 Toomer (1984); Evans and Berggren (2006).

astronomy is the texts themselves, and the *Thesaurus Linguae Graecae* text bank[42] is a powerful tool for locating parallel usages within an author as well as across the surviving scientific literature.

7.1 Terms for astronomy and its practitioners

For Theon, ἀστρονομία and ἀστρολογία both refer to the mathematical science (μάθημα) of the heavenly bodies,[43] though interestingly, ἀστρονομία is consistently employed in the first pages of his work as well as in the passages that mark the transitions from the section on means to that on astronomy and from the section on astronomy to that on cosmic harmonies,[44] whereas in the section on astronomy itself he consistently uses ἀστρολογία.[45] Similarly, in the earlier part of his work he designates the practitioner of the science as ἀστρονόμος[46] or ἀστρονομῶν[47] but, just once and in the plural, as ἀστρολογήσαντες in the part on astronomy.[48] Elsewhere in this section, and *only* in this section, μαθηματικός means a practitioner of astronomy (always used in the plural).[49] There may be significance in the fact that Theon's μαθηματικοί are always associated with theoretical issues, especially the "hypotheses" underlying the apparent motions of the heavenly bodies, whereas an ἀστρονόμος or ἀστρονομῶν could be someone like Hesiod who is concerned only with the immediate celestial appearances, though such a person is not a "genuine"

42 http://www.tlg.uci.edu.
43 Astrology in the modern sense is not discussed by Theon, though the obscure passage at H177.16–18 concerning the motivation of Babylonian, Chaldean, and Egyptian astronomy may be alluding to astrological prediction.
44 The occurrences are at H1–17 (nine instances, for which see Hiller's index), H93.10–11, H119.20–21 (first transitional passage), and H205.4 (second transitional passage).
45 Three instances at H199.12, H204.22, H204.22, and H205.2, in addition to the title of a work Ἀστρολογίαι by Eudemos at H198.14. Theon's fluctuating usage doubtlessly reflects the dichotomy between Plato's consistent use of ἀστρονομία and Aristotle's of the more traditional ἀστρολογία; see Hübner (1989): 13–16.
46 H9.8 and H16.9.
47 H9.9.
48 H177.22–23, within the passage translated here.
49 H143.1, H154.13–14, H172.21, H177.10 (apparently encompassing Babylonians, Chaldeans, and Egyptians), H179.5, H185.13, H189.17, H194.10, and H201.25 (applied to Menaichmos and Kallippos in contrast to Aristotle). μαθηματικός is Ptolemy's word for an astronomer throughout the *Almagest*, paralleling his classifying the field of astronomy (which he never names as such in that treatise) as part of the μαθηματικόν, "mathematical", class of theoretical philosophy.

(ἀληθῶς) astronomer.[50] Historically, ἀστρολόγος and ἀστρονόμος were established well before μαθηματικὸς began to be used in the specific sense of "astronomer", and one might suspect that this usage entailed a conscious appeal to the epistemic prestige of mathematical reasoning. In any case, it is appropriate, at least in the case of Theon, to translate words derived from either ἀστρονομία or ἀστρολογία using "astronomy" and its derivatives. An entirely transparent rendering of μαθηματικός does not seem possible if we wish to observe the distinction from ἀστρολόγος and ἀστρονόμος, but I can see no better alternative to "mathematician".

7.2 Heavenly bodies

Theon uses the noun πλάνης, the nominalized neuter adjective πλανητόν (apparently only in the plural), and, most frequently, the nominalized masculine participle πλανώμενος to designate any of the seven heavenly bodies that are not "fixed", i.e. the Sun, the Moon, Mercury, Venus, Mars, Jupiter, and Saturn. There does not seem to be a rationale determining which form he employs in any specific context. In the chosen passage he frequently differentiates between the Sun and the "other" πλανώμενοι, and once distinguishes the Sun and Moon together from the "five" (*scil.* πλανώμενοι). In modern English, "planet" is not normally applicable to the Sun or Moon, so a translator who wishes to use this word ought either to explain by way of commentary that "planets" encompasses the Sun and Moon or, less satisfactorily, to use glosses such as "the (Sun, Moon, and) planets" or "the other planets (including the Moon)". I have instead rendered πλάνης and πλανητόν literally as "wanderer" and πλανώμενος as "wandering (star)", making visible the fundamental criterion for treating all seven bodies as a single type of object.

In the passage, only the Sun and Moon are specifically named (ἥλιος and σελήνη), and I have chosen to translate them as "Sun" and "Moon" since in the context of Theon's astronomical discussions mythological associations do not come into play and so there seems to be no benefit in retaining the Greek names in translation as "Helios" and "Selene".[51] Elsewhere in the astronomical section, Theon employs both the established systems of nomenclature for the five planets (in the modern sense) known in antiquity, that is, the descriptive names

50 H9.7–11, closely following the Platonic *Epinomis* 990a.

51 Hence my treatment of these names differs from that adopted by Stephan Heilen for an astrological text in his contribution to this volume.

Στίλβων, Φώσφορος, Πυρόεις, Φαέθων, Φαίνων, and the theophoric names ὁ τοῦ Ἑρμοῦ / τῆς Ἀφροδίτης / τοῦ Ἄρεως / τοῦ Διός / τοῦ Κρόνου (*scil.* ἀστήρ). The descriptive names lend themselves easily to literal translation, e.g. as (respectively) "Gleamer","Lightbearer", "Fiery One", "Radiant One", and "Shiner". The usual practice of translators is to render the theophoric expressions by the common modern names Mercury, Venus, Mars, Jupiter, and Saturn which of course come from the Latin tradition, omitting the possessive construction; this makes it easy for the modern reader to identify the objects. Following the approach adopted in the present translation, I would translate them as "the (star) of Hermes/Aphrodite/Ares/Zeus/Kronos".

7.3 Directional terms

In both Greek geography and astronomy, μῆκος ("length") and πλάτος ("breadth") are used for what from a modern perspective we loosely describe as "spherical coordinates". In geography, "length" means the angular east-west separation between the meridians passing through two localities or between the meridian through a single locality and a reference meridian, measured along the terrestrial equator, i.e. modern geographical "longitude", and "breadth" means the angular north-south separation between a locality and the terrestrial equator, measured along the meridian through the locality, i.e. modern geographical "latitude". Greco-Roman maps of the known world tended to display a greater east-west extent than their north-south extent, so the terminology concords with the common usage of "length" and "breadth" respectively for the longer and shorter perpendicular dimensions of, say, a rectangular plot of land.

In astronomy, "length" normally means position or motion measured along or parallel to the ecliptic, and "breadth" normally means position or motion north or south of the ecliptic, measured along a great circle through the ecliptic's poles, i.e. modern astronomical "longitude" and "latitude" respectively.[52] But there is also a third astronomical dimension, "depth" (βάθος), which refers to position or motion towards or away from the Earth (or the center of the cosmos). Theon also uses ἀνωμαλία, "nonuniformity", to designate this dimension, because in the epicyclic and eccentric models that Theon associates with the heavenly bodies, variation in apparent speed and direction of a heavenly body's

52 There are instances in other authors, though not in Theon, of πλάτος used to designate separation from the celestial equator, i.e. modern "declination".

motion is correlated with variation in the body's actual distance from the center of the cosmos.[53]

I render μῆκος and πλάτος as "length" and "breadth" (rather than the usual "longitude" and "latitude") to make visible the systematic transfer of the standard terminology for dimensions of three-dimensional everyday objects to celestial motions, as well as the connection of πλάτος to Theon's earlier characterization of the zodiacal circle as a belt having "breadth" (ἐν πλάτει τινί) in contrast to the celestial equator and tropic circles, which are mere lines.[54] For ἀνωμαλία I use "nonuniformity" instead of the more abstract "anomaly" since for the Platonist Theon the contrast between the uniform motion that properly applies to eternal celestial entities and their apparent nonuniform motion as seen from the Earth is a crucial issue in astronomy.

Nowhere does modern astronomical terminology (and the underlying way of thinking) conflict more with ancient Greek terminology than in the expressions relating to "forward" and "backward" apparent motion of heavenly bodies. The modern terms reflect an essentially sidereal frame of reference: since the prevailing direction in which the planets move through the zodiac (and the *only* direction in the case of the Sun and Moon) is eastwards, eastward longitudinal motion is characterized as "direct" and westward motion is "retrograde". From the Greek geocentric perspective, the fundamental motion for all heavenly bodies is the daily revolution of the heavens, on account of which all the stars, Sun, Moon, and planets rise in the east and set in the west; westward motion of a heavenly body relative to the stars is thus "forward" motion and eastward is "backward". Depending on context, the verb προηγεῖται ("leads") means either "is west of" or "moves westwards", while ὑπολείπεται ("trails") means either "is east of" or "moves eastwards". A planet's retrogradation is called a προήγησις, "leading". The expressions εἰς τὰ προηγούμενα, "towards the leading" (*scil.* stars or zodiacal signs), and εἰς τὰ ἑπόμενα ("towards the following") also mean respectively westwards and eastwards. I have translated all such terms literally. Whereas in the *Almagest* Ptolemy so to speak filters out the daily revolution in developing his theories of the heavenly bodies, in Theon's discussions of celestial motions we are seldom allowed to forget that the daily rotation of the heavens is the *fundamental* cosmic motion, to which all the other revolutions involved in planetary motion must be referred.

53 This correlation is discussed previously by Theon, H135.6–11.

54 H133.17–20.

7.4 Appearances and realities

Theon employs the verb δοκεῖ to signify a false visual or conceptual appearance ("seems" in my rendering), whereas φαίνεται signifies a more neutral empirical appearance ("appears"); to keep the close relation to the verb, I translate φαινόμενα as "appearances" rather than "phenomena". For the theoretically apprehended realities, such as epicycles or eccentric circles, underlying the appearances, Theon has three words: ἀρχή (here rendered "first principle"), ὑπόθεσις ("hypothesis"), and πραγματεία ("approach"). Although he occasionally pairs ὑποθέσεις with ἀρχαί or with πραγματεῖαι, it is not clear whether there is a strong differentiation between these terms. Appearances that arise as an inessential consequence of the realities in combination with external circumstances, e.g. because we observe the realities from a displaced viewpoint, are said to occur κατὰ συμβεβηκός; in philosophical texts this expression is traditionally but misleadingly translated "by accident", whereas I prefer "by happenstance" to bring out the relation to the verb συμβαίνειν, "to happen".[55]

7.5 Geometry

The selection translated below does not contain formal geometrical demonstrations, but we do have discussion of two geometrical diagrams involving a few common terms, chiefly "circle" (κύκλος) and "center" (κέντρον). Other passages of the astronomical part of Theon's book make more extensive use of the technical language of Greek geometry. Although some terms of Greek geometry also have related everyday senses, such as "sharp point" for κέντρον, no useful purpose would be served by representing them by such translations. The language of Greek deductive mathematics, both its vocabulary and its syntax, were highly restricted, standardized, and immediately recognizable; whatever he may say about his work's being accessible to utter beginners, in practice Theon presumed his reader to be already acquainted with this language at least at the level of the first books of Euclid's *Elements*.

55 Martin ([1849]: 368–370) has a valuable note on Theon's use of κατὰ συμβεβηκός.

8 Text and Translation[56]

[172] |15ταῦτα δὲ καὶ ἐπὶ τῶν ἄλλων πλανωμένων δείκνυ|16ται, πλὴν ὁ μὲν ἥλιος ἀπαραλλάκτως ταῦτα δοκεῖ ποιεῖν |17κατὰ ἀμφοτέρας τὰς ὑποθέσεις, διὰ τὸ τοὺς ἀποκατα|18στατικοὺς αὐτοῦ χρόνους, τόν τε τοῦ μήκους καὶ τὸν |19τοῦ πλάτους καὶ τὸν τοῦ βάθους καὶ [τὸν] τῆς λεγο|20μένης ἀνωμαλίας, οὕτως εἶναι σύνεγγυς ἀλλήλων, ὥστε |21τοῖς πλείστοις τῶν μαθηματικῶν ἴσους δοκεῖν, ἡμερῶν |22ἕκαστον τξε δʹ, ἀκριβέστερον δὲ ἐπισκοπουμένοις

- τὸν |23μὲν τοῦ μήκους, ἐν ᾧ τὸν ζῳδιακὸν ἀπὸ σημείου τινὸς |24ἐπὶ τὸ αὐτὸ σημεῖον διανύει καὶ ἀπὸ τροπῆς ἐπὶ τὴν [173] |1αὐτὴν τροπὴν καὶ ἀπὸ ἰσημερίας ἐπὶ τὴν αὐτὴν ἰση|2μερίαν παραγίνεται, τὸν εἰρημένον σύνεγγυς [κύκλον] |3χρόνον, παρὰ τετραετίαν ἐπὶ τὸ αὐτὸ σημεῖον τοῦ μή|4κους, αὐτοῦ κατὰ τὴν αὐτὴν ὥραν ἀποκαθισταμένου,
- |5τὸν δὲ τῆς ἀνωμαλίας, καθ᾿ ὃν ἀπογειότατος γινόμενος |6καὶ δι᾿ αὐτὸ τῇ μὲν φάσει τοῦ μεγέθους μικρότατος, |7βραδύτατος δὲ κατὰ τὴν είς τὰ ἑπόμενα φοράν, ἢ ἀνά|8παλιν προσγειότατος καὶ

[172] |15These things are also demonstrated for the other wandering (stars), |16except that the Sun seems to do these things undivergingly |17according to both hypotheses, because of the fact that |18its periods of restitution, that |19of length and that of breadth and that of depth and what is |20called nonuniformity, are so close to each other that |21they seem to the majority of the mathematicians to be equal, |22each one 365 1/4 days, but to those who make inquiry more precisely,

- that |23of the length, in which it traverses the zodiacal (circle) from some point |24to the same point and returns from turning to the [173] |1same turning and from equinox to the same |2equinox, the stated approximate |3time-interval, with it (i.e. the Sun) being restituted by a four-year-interval to |4the same point of length at the same hour,
- |5that of the nonuniformity, according to which becoming furthest from the Earth |6and because of this smallest in the appearance of size and |7slowest with respect to the motion towards the trailing (stars), or |8contrariwise

56 Page numbers in Hiller's edition are given in brackets, and line numbers by superscript numerals. The line divisions are necessarily indicated only approximately in the translation since the word order is not always the same as in the Greek.

διὰ τοῦτο μέγιστος μὲν τῷ |9μεγέθει δοκῶν, τῇ δὲ κινήσει τάχιστος, ἡμερῶν ἔγγιστα |10τ̅ξ̅ε̅ ∠, διετίᾳ πάλιν ἐπὶ τὸ αὐτὸ σημεῖον τοῦ βάθους ⟨κατὰ⟩ |11τὴν αὐτὴν ὥραν αὐτοῦ φαινομένου,

(becoming) nearest to the Earth and because of this seeming greatest in |9size and fastest in motion, comprising |10365 1/2 days approximately, with it (i.e. the Sun) appearing in a two-year-interval again <at> the same point of depth at |11the same hour,

- τὸν δὲ τοῦ πλά|12τους, ἐν ᾧ ἀπὸ τοῦ αὐτοῦ βορειότατος ἢ νοτιώτατος |13γενόμενος ἐπὶ τὸ αὐτὸ παραγίνεται, ὡς πάλιν ἴσας |14ὁρᾶσθαι τὰς τῶν αὐτῶν γνωμόνων σκιάς, ἡμερῶν μά|15λιστα τ̅ξ̅ε̅ η′, κατὰ τὸ αὐτὸ τοῦ πλάτους σημεῖον αὐτοῦ ⟨κατὰ⟩ |16τὴν αὐτὴν ὥραν ὀκταετίᾳ παραγινομένου

- and that of |12breadth, in which from the same (condition of) |13being furthest north or furthest south, it returns to the same (condition), so that the shadows of the same gnomons |14are seen as again equal, comprising 365 1/8 days |15actually, with it (i.e. the Sun) returning to the same point of the breadth <at> |16the same hour in an eight-year-interval;

ἐπὶ δὲ τῶν |17ἄλλων, ἐπεὶ καθʼ ἕκαστον τῶν πλανωμένων πολὺ παραλ|18λάττουσιν ⟨οἱ⟩ εἰρημένοι χρόνοι πάντες, καὶ ἐφʼ ὧν |19μὲν μᾶλλον, ἐφʼ ὧν δὲ ἧττον, τὰ γινόμενα καθʼ ἕκα|20στον φαίνεται ποικιλώτερα καὶ διαλλάττοντά πως καθʼ |21ἑκατέραν τὴν ὑπόθεσιν, οὐκέτʼ ἐν ἴσῳ χρόνῳ τοῦ πλά|22νητος ἑκάστου τὸν ἑαυτοῦ ἐπίκυκλον περιερχομένου καὶ |23τοῦ ἐπικύκλου τὸν ἔγκεντρον, ἀλλʼ ὧν μὲν θᾶττον, ὧν |24δὲ βράδιον, διά τε τὰς τῶν κύκλων ἀνισότητας καὶ διὰ [174] |1τὰς ἀπὸ τοῦ μέσου τοῦ παντὸς ἀνίσους ἀποστάσεις, ἔτι |2τε διὰ τὰς πρὸς τὸν διὰ μέσων τῶν ζῳδίων διαφόρους |3λοξώσεις ἢ ἀνομοίους ἐγκλίσεις τε καὶ θέσεις. ὅθεν καὶ |4τὰ τῶν στηριγμῶν τε καὶ ἀναποδισμῶν καὶ προηγήσεων |5καὶ ὑπολείψεων οὐχʼ ὁμοίως ἐπὶ πάντων ἀπαντᾷ, ἀλλʼ

but in the case of the |17others, since <the> stated time-intervals |18are all very divergent in the case of each of the wandering (stars), and |19more so in the case of some and less so in the case of others, the things that occur with respect to |20each appear more complicated and somehow disparate according to |21either of the hypotheses, since it is no longer the case that each one's |22wanderer goes around its own epicycle and |23the epicycle (goes around) the concentric (circle) in an equal time-interval, but for some of them faster and for |24others slower, both because of the inequalities of the circles and because of [174] |1the unequal distances from the middle of the whole, and moreover |2because of the different obliquities or dissimilar |3inclinations and positions with respect to the (circle) through the middles of the zodiacal signs. This is why |4the (matters) of the standings-still and

|6ἐπὶ μὲν τῶν ε̅ γίνεσθαι [ὡς] ταῦτα φαίνεται, εἰ καὶ |7μὴ παντάπασιν ὁμοίως, ἐπὶ μέντοι γε ἡλίου καὶ σελή|8νης οὐδ᾽ ὅλως. οὔτε γὰρ προηγεῖσθαί ποτε οὔτε στηρί|9ζειν οὔτε ἀναποδίζειν οὗτοι φαίνονται, διὰ τὸ τὸν μὲν |10ἥλιον σύνεγγυς κατὰ τὸν ⟨αὐτὸν⟩ χρόνον ἐπὶ τοῦ αὐ|11τοῦ κύκλου φαίνεσθαι φερόμενον, καὶ τὸν ἐπίκυκλον |12αὐτοῦ κατὰ τοῦ ἐγκέντρου, καθάπερ ἔφαμεν, τῆς δὲ |13σελήνης τὸν ἐπίκυκλον θᾶττον κατὰ τοῦ ἐγκέντρου φέ|14ρεσθαι καὶ τοῦ τῶν ζῳδίων ὑπολείπεσθαι κύκλου ἢ |15αὐτὴν διεξιέναι τὸν ἐπίκυκλον.

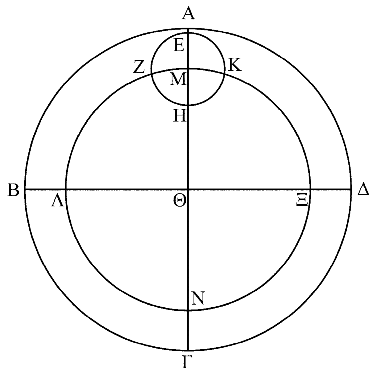
reversals |5and goings-forward and fallings-behind do not happen in like manner in the case of all; but |6in the case of the five, these things are apparent, albeit |7not similarly for all; but in the case of |10Sun and |8Moon not at all; for these do not appear ever to go forward or |9stand still or reverse direction, because of the fact that the |10Sun appears as being borne in very nearly the same time-interval on |11its own circle as its epicycle (is borne) |12on the concentric (circle), just as we said, whereas the |13Moon's epicycle (appears) to be borne faster on the concentric (circle) |14and to fall behind on the circle of the zodiacal signs than |15(the Moon) itself (appears) to make the circuit of the epicycle.

[175] |1δῆλον δὲ ὡς οὐδὲν διαφέρει πρὸς τὸ σώζειν τὰ |2φαινόμενα, τοὺς πλάνητας κατὰ τῶν κύκλων, ὡς διώ|3ρισται, λέγειν κινεῖσθαι, ἢ τοὺς κύκλους φέροντας τὰ |4τούτων σώματα αὐτοὺς περὶ τὰ ἴδια κέντρα κινεῖσθαι· |5λέγω δὲ τοὺς μὲν ἐγκέντρους, φέροντας τὰ τῶν ἐπικύ|6κλων κέντρα, περὶ τὰ αὑτῶν κέντρα κινεῖσθαι ὑπεναν|7τίως ⟨τῷ παντί⟩, τοὺς δὲ ἐπικύκλους, φέροντας τὰ τῶν |8πλανωμένων σώματα, πάλιν περὶ τὰ αὑτῶν κέντρα, οἷον |9τὸν μὲν ΜΛΝΞ ἔγκεντρον φέρεσθαι περὶ τὸ Θ, τοῦ παν|10τὸς καὶ ἑαυτοῦ κέντρον, ὑπεναντίως τῷ παντί, φέροντα |11ἐπὶ τῆς αὑτοῦ περιφερείας τοῦ ⟨ἐπικύκλου τὸ⟩ Μ κέν|12τρον, τὸν ⟨δὲ⟩ ΕΖΗΚ ἐπίκυκλον ἔχοντα τὸν πλανώμενον |13κατὰ τὸ Ε φέρεσθαι πάλιν περὶ τὸ Μ κέντρον, ἐπὶ μὲν

[175] |1It is obvious that it makes no difference for saving the |2appearances to say that the wanderers move along the circles, in the way |3that has been defined, or that the circles, bearing the |4bodies of these (*scil.* the wandering stars), themselves move around their distinct centers –|5I mean that the concentric (circles), bearing the centers of the |6epicycles, move around their own centers in the |7opposite sense <to the whole>, and that the epicycles, bearing the bodies of the |8wandering (stars), again (move) around their own centers, for example |9the concentric (circle) ΜΛΝΞ is borne around (point) Θ, the center of the |10whole and of itself, in the opposite sense to the whole, while bearing |11on its periphery the center M of the epicycle, |12and the epicycle EZHK having the planet |13at E is borne again around the center M, in the case of the |14Sun and Moon in the same direction

|14ἡλίου καὶ σελήνης ἐπὶ τὰ αὐτὰ τῷ παντί, ἐπὶ δὲ τῶν |15ἄλλων καὶ τοῦτον ὑπεναντίως τῷ παντί· σώζεται γὰρ |16οὕτως τὰ φαινόμενα.

as the whole, but in the case of the |15others this too in the opposite sense to the whole; for |16in this way the appearances are saved.

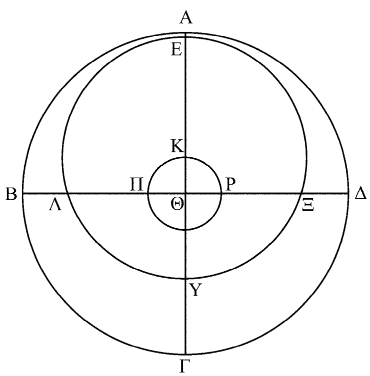


|17κατὰ δὲ τὴν ἑτέραν πραγματείαν, ὄντος ἐκκέντρου [176] |1κύκλου τοῦ ΕΛΝΞ περὶ κέντρον τὸ Κ, ἐπὶ μὲν ἡλίου αὐτὸς |2ὁ ΕΛΝΞ κύκλος ἐν ἐνιαυτῷ κινούμενος ὁμαλῶς περὶ τὸ |3Κ κέντρον, φέρων τὸν ἥλιον ἐνεστηριγμένον κατὰ τὸ Ε |4σημεῖον, σώσει τὰ φαινόμενα, τοῦ Κ κέντρου καθ' ἑαυτὸ |5μὲν μὴ κινουμένου μηδ' ὑπεναντίως τῷ παντί, συναπο|6φερομένου δὲ τῷ παντὶ καὶ πρὸς ἡμέραν ἑκάστην γρά|7φοντος τὸν ΚΡΠ κύκλον, ἴσον γινόμενον τῷ τῆς ἑτέρας |8πραγματείας κύκλῳ· ποιήσεται γὰρ οὕτως ὁ ἥλιος ἀεὶ |9κατὰ τοὺς αὐτοὺς τόπους μέγιστα ἀποστήματα καὶ πάλιν |10καθ' ἑτέρους ἐλάχιστα καὶ παραπλησίως κατὰ ἄλλους |11μέσα, τὰ μὲν μέγιστα κατὰ τὴν ε΄ ∠ μοῖραν, ὡς εἴρηται, |12τῶν Διδύμων, τὰ δὲ ἐλάχιστα κατὰ τὴν αὐτὴν τοῦ |13Τοξότου, καὶ τὰ μέσα ὁμοίως κατὰ τὰς αὐτὰς τῆς τε

|17According to the other approach, with there being an eccentric [176] |1circle ΕΛΥΞ around center K, in the case of the Sun the circle |2ΕΛΥΞ, moving in a year uniformly around the |3center K, bearing the Sun fixed upon it at |4point E, will save the appearances, with the center K by itself |5not moving, not even in the opposite sense to the whole, but |6being borne together with the whole and |7describing on each day the circle ΚΡΠ, which comes to be equal to the circle of the other |8approach; for in this way the Sun will always make the greatest distances |9at the same places, and again |10the least (distances) at other (places) and analogously |11mean (distances) at other (places), the greatest at the 5 $^1/_2$th degree of |12the Twins, as has been said, and the least at the same (degree) of the |13Archer, and the means similarly at the same (degrees) of the |14Maiden and the Fishes; since also the point E |15of the eccentric

|14Παρθένου καὶ τῶν Ἰχθύων· ἐπειδὴ καὶ τὸ Ε σημεῖον |15τοῦ ἐκκέντρου ἐφ᾽ οὗ ἐστιν ὁ ἥλιος, τήνδε μὲν ἔχοντος |16τὴν θέσιν τοῦ κύκλου, φαινόμενον ὑπὸ τοὺς Διδύμους |17ἀπογειότατόν ἐστιν, περιενεχθέντος δὲ τοῦ κύκλου περὶ |18τὸ Κ κέντρον, μεταπεσὸν ὅπου νῦν ἐστι τὸ Υ, φανή|19σεται μὲν ὑπὸ τὸν Τοξότην, ἔσται δὲ προσγειότατον, |20μεταξὺ δὲ τούτων, κατά τε τὴν Παρθένον καὶ τοὺς |21Ἰχθύας, μέσως ἀποστήσεται.

(circle) on which the Sun is, when the circle has this |16position, appearing to be under the Twins, is |17furthest from the Earth, but with the circle turned around |18the center K, (point E), falling where the (point) Y is now, |19will appear to be under the Archer, and it will be nearest to the Earth, |20and between these, at the Maiden and the |21Fishes, it will be in a mean situation.



|22τὰ δ᾽ ἄλλα πλανητὰ ἐπειδὴ κατὰ πάντα τόπον τοῦ |23ζῳδιακοῦ καὶ μέγιστα καὶ ἐλάχιστα καὶ μέσα ποιεῖται |24καὶ ἀποστήματα καὶ κινήματα, ἐὰν κέντρῳ μὲν τῷ Θ |25τοῦ παντός, διαστήματι δὲ τῷ ΘΚ, γεγράφθαι νοήσω|26μεν κύκλον τὸν ΚΠΡ, ἔπειτα τοῦτον, ἔγκεντρον ὄντα καὶ [177] |1ἴσον τῷ τῆς ἑτέρας ὑποθέσεως ἐπικύκλῳ, φέρεσθαι περὶ |2τὸ Θ τοῦ παντὸς κέντρον καὶ συναποφέρειν τὸ Κ κέν|3τρον τοῦ ἐκκέντρου ὑπεναντίως τῷ παντὶ ἐν χρόνῳ |4τινί, τὸν δὲ ΕΛΥΞ ἔκκεντρον ἐν ἑτέρῳ χρόνῳ κινεῖσθαι |5περὶ τὸ

|22Since the other wanderers at every place of the |23zodiacal (circle) make greatest and least and mean |24distances and motions, if with (point) Θ as center of |25the whole and radius ΘK, let us conceive as having been described |26the circle KΠP, and next, (let us conceive of) this (circle), being concentric with and [177] |1equal to the epicycle of the other hypothesis, as being borne around |2the center Θ of the whole, and (let us conceive of this circle as) bearing the center K |3of the eccentric (circle) away together with itself in the opposite sense to the whole in a certain time-interval, |4and that the eccentric

ἑαυτοῦ κέντρον τὸ Κ, φέροντα τὸν πλανώμενον |6ἐνεστηριγμένον ἐν αὐτῷ κατὰ τὸ Ε, λαμβανομένων τῶν |7χρόνων καθ᾽ ἕκαστον τῶν πλανωμένων ἰδίων καὶ |8οἰκείων, σωθήσεται τὰ φαινόμενα.
|9καὶ ταῦτα μὲν ἐπὶ πλέον διέξεισι τοῦ προσεικειῶσαι |10ἀλλήλαις τὰς τῶν μαθηματικῶν ὑποθέσεις τε καὶ πραγμα|11τείας, οἵτινες πρὸς τὰ φαινόμενα μόνον καὶ τὰς κατὰ |12συμβεβηκὸς γινομένας τῶν πλανωμένων κινήσεις ἀπο|13βλέποντες, μακροῖς χρόνοις ταύτας τηρήσαντες διὰ τὸ |14εὐφυὲς τῆς χώρας αὐτῶν, Βαβυλώνιοι καὶ Χαλδαῖοι |15καὶ Αἰγύπτιοι, προθύμως ἀρχάς τινας καὶ ὑποθέσεις |16ἀνεζήτουν, αἷς ἐφαρμόζει τὰ φαινόμενα· δι᾽ οὗ τὸ κατὰ |17τὰ εὑρημένα πρόσθεν ἐπικρίνειν καὶ κατὰ μέλλοντα |18προλήψεσθαι, φέροντες οἱ μὲν ἀριθμητικάς τινας, ὥσπερ |19Χαλδαῖοι, μεθόδους, οἱ δὲ καὶ γραμμικάς, ὥσπερ Αἰ|20γύπτιοι, πάντες μὲν ἄνευ φυσιολογίας ἀτελεῖς ποιού|21μενοι τὰς μεθόδους, δέον ἅμα καὶ φυσικῶς περὶ τού|22των ἐπισκοπεῖν· ὅπερ οἱ παρὰ τοῖς Ἕλλησιν ἀστρολογή|23σαντες ἐπειρῶντο ποιεῖν, τὰς παρὰ τούτων λαβόντες |24ἀρχὰς καὶ τῶν φαινομένων τηρήσεις, καθὰ καὶ Πλάτων [178] |1ἐν τῷ Ἐπινομίῳ μηνύει, ὡς ὀλίγον ὕστερον ἔσται δῆλον |2παρατεθεισῶν τῶν λέξεων αὐτοῦ.

(circle) ΕΛΥΞ moves in a different time-interval |5around its own center, K, bearing the planet |6fixed upon it at the (point) E, such that the |7time-intervals are taken as distinct and |8proper for each of the planets, the appearances will be saved.
|9And he expounds these things at greater length with a view to accommodating |10to each other the hypotheses and |11approaches of the mathematicians, who, while giving regard only to the appearances and the |12motions of the wandering (stars) that occur by happenstance, |13having observed them for long time-intervals because of the |14natural suitability of their country – (I mean) the Babylonians and Chaldeans |15and Egyptians – eagerly sought certain first principles and hypotheses, |16to which the appearances fit; by means of this (they would be able) to make judgment with respect to |17the things found before and to forecast with respect to things going to happen, |18some of them adducing certain numerical methods, like |19the Chaldeans, and others (adducing) graphical (methods), like |20the Egyptians, but all (of them) making |21their methods incomplete without reasoning according to nature, whereas it is needful at the same time |22to make examination concerning these things in a nature-related manner; and this is the very thing that those among the Greeks who |23engaged in astronomy tried to do, taking |24the first principles and the observations of the appearances from these (people), just as Plato discloses [178] |1in the *Epinomion*, as will be clear a little later |2when his statements have been laid out.

9 Commentary

H172.15–173.16 This is by Theon's standards an exceptionally long and complex sentence. Rather than break it up into shorter sentences, I have used indentation and bullet points in both the text and translation to make the structure of the sentence more evident and to bring out the parallel descriptions of the Sun's three periodicities. For grammatical reasons I have inserted κατά at both H173.11 and H173.16.

H172.15 *These things are also demonstrated*: At H152.8–10 Theon singled out the Sun to serve as an example of how each of the Sun, Moon, and planets produce an appearance of changing speed and, in some cases, changing direction of motion while in reality moving uniformly on their spheres. The passage devoted to the Sun comprised an account of a phenomenon indicating an apparent non-uniform motion of the Sun, namely the inequality of the four seasons demarcated by the solstices and equinoxes (H152.11–153.15), demonstrations of how a simple eccentric hypothesis or alternatively a simple epicyclic hypothesis could generate this inequality (H153.16–166.3), and demonstrations of the fact that the epicyclic hypothesis generates a path for the Sun identical to the eccenter of the eccentric hypothesis and *vice versa* (H166.4–172.14). The reader will naturally infer that the expression "these things" at H172.15 refers to the compatibility of the phenomena exhibited by the Moon and planets with epicyclic and eccentric hypotheses as well as the mutually generating relationship of the two kinds of hypothesis when applied to these other bodies.

The corresponding passage of Calcidius (Waszink [1962]: 125–134) begins likewise with the choice of the Sun as an example, and continues with the description of the inequality of the seasons and the demonstrations that both the eccentric and the epicyclic hypotheses generate the inequality. This is followed immediately (Waszink [1962]: 134–135) by a transition to the general discussion of the applicability of the hypotheses to all seven heavenly bodies, which corresponds at least roughly to parts of Theon H172.15–174.15. The absence of the "equivalence" demonstrations from Calcidius does not indicate that they were also absent from Adrastos, since Theon expressly attributes to Adrastos the demonstration that the eccenter follows as a consequence of the epicyclic hypothesis, and probably also the converse demonstration.[57]

57 Theon writes (H166.10): δείκνυσι δὲ ὁ Ἄδραστος πρῶτον μὲν πῶς τῇ κατ᾽ ἐπίκυκλον ἕπεται κατὰ συμβεβηκὸς ἡ κατὰ ἔκκεντρον· ὡς δὲ ἐγώ φημι, καὶ τῇ κατὰ ἔκκεντρον ἡ κατ᾽ ἐπίκυκλον, "Adrastos demonstrates firstly how the (hypothesis) according to eccenter follows by

But it is conceivable that Theon moved the demonstrations here from some other location in Adrastos's commentary.

H172.16 *undivergingly*: The point of this adverb (ἀπαραλλάκτως) is not that the two hypotheses produce the same phenomena as each other only in the case of the Sun but rather that the phenomena generated by the hypotheses for the Sun, specifically the lengths of the seasons, do not change from cycle to cycle, whereas appropriate epicyclic or eccentric hypotheses for the other bodies would have to account for phenomena that are inconstant in certain respects, e.g. in their locations in the zodiac, because they are affected by components in the bodies' motions that have different periodicities.

Whereas Calcidius (Waszink [1962]: 134) asserts that the Sun completes its cycles of irregular motion (*intemperies*) with respect to "depth", i.e. anomaly (*cum exaltatur uel cum humiliatur*) and "breadth", i.e. latitude (*cum a medietate ad diuersas caeli plagas discedit*) in one year (*eamque omnem intemperiem anni uertentis termino claudit*), Theon writes that this is only approximately so. Perhaps he is here diverging from Adrastos and incorporating elements of a solar theory that was current in his own time, since he is not this time confronting the views of the "mathematicians" (cf. section 7.1) with those of the philosophers, but rather the views of "the majority of the mathematicians" (τοῖς πλείστοις τῶν μαθηματικῶν) with other mathematicians who have looked into the matter with greater exactitude (ἀκριβέστερον δὲ ἐπισκοπουμένοις). The three periodicities that Theon cites, 365 $^1/_4$ days (for motion in longitude), 365 $^1/_2$ days (in anomaly), and 365 $^1/_8$ days (in latitude) are in fact the basis of a table of mean motions of the Sun in the second-century papyrus *POxy astron.* 4174a.[58] The differences between these solar periodicities are comparable to those between the corresponding lunar periodicities of longitude, anomaly, and latitude (which Theon, oddly, never expressly mentions), though in proportion to the periodicities themselves they are an order of magnitude smaller.[59]

happenstance the (hypothesis) according to epicycle; and, as I say, the (hypothesis) according to epicycle also (follows) the (hypothesis) according to eccenter". The structure of the sentence strongly suggests that Adrastos demonstrated both, and "as I say" is merely a reminder that Theon (following Adrastos) has already spoken of the mutual derivability of the hypotheses (H154.12–23), not an assertion that Theon has added the converse on his own initiative.

58 Jones (1999): 1.170–171 and 2.164–167.

59 The Moon's periods of longitude, anomaly, and latitude could crudely be approximated as 27 $^1/_3$ days, 27 $^1/_2$ days, and 27 $^1/_5$ days respectively. Theon's solar theory implies that the solar nodes decrease in longitude while the solar apsidal line (the line through the apogee and perigee) increases, just as is the case for the Moon.

Previously (H135.12–14) Theon has stated that the Sun has a range of latitudinal motion of about 1°, i.e. $\pm {}^1/_2{}^\circ$ relative to the ecliptic; and since this passage is also in Calcidius (Waszink [1962]: 117, cf. also Waszink [1962]: 139 paralleling Theon H194.4–8), the principle of a solar motion in latitude, if not the specific periodicity associated by Theon with it, probably was in Adrastos's commentary. Yet a solar theory attributing to the Sun a motion in latitude does not appear to be consistent with the more or less Hipparchian theory accepted by Adrastos in his demonstrations concerning the hypotheses for the Sun. An inclination of the plane of the Sun's path of motion relative to the plane of the ecliptic would mean that the observed dates of solstices and equinoxes would generally not be the same as the dates when the Sun is at the beginnings of the zodiacal signs Aries, Cancer, Libra, and Capricorn, if those points are defined as the intersections of the ecliptic with the equator.[60] Moreover, having a period of anomaly different from the period of longitude would require a moving apogee and perigee in an eccentric hypothesis or, in an epicyclic hypothesis, a period of revolution of the Sun around its epicycle different from the epicycle's period of revolution around the Earth, and the lengths of the astronomical seasons would accordingly change from one year to the next. However, since the presumed differences between the periodicities are small and would have negligible effect over a single year, Theon (and Adrastos himself) would be justified in accepting Adrastos's demonstrations for didactic purposes.

H172.23–24 *it traverses the zodiacal (circle) from some point to the same point and returns from turning to the same turning and from equinox to the same equinox*: Theon offers three criteria for this periodicity, implying that they are interchangeable. Turning (τροπῆς) clearly means solstice here, that is, a reversal of the Sun's north-south motion relative to the celestial equator, which is the common meaning of the word in astronomical contexts. (Theon employs τροπή at H148.21 for points or times of reversal of north-south motion of other heavenly bodies.) Hence the second and third criteria amount to a definition of a tropical year.

The sense of "point" (σημεῖον) is less evident. Theon appears to be contrasting a spatial definition of the year in terms of the Sun's consecutive passages of a certain geometrical point on the ecliptic ("zodiacal [circle]") to a

60 Neugebauer ([1975]: 629) points out that the ancient sources that attribute motion in latitude to the Sun do not explain precisely what the ecliptic is, if it cannot be defined as the apparent path of the Sun. A workable definition would be the great circle whose northern and southern limits, relative to the equator, occupy the mean positions of the northern and southern limits of either the Sun's or the Moon's motion over an entire period of latitudinal motion.

temporal definition in terms of the *dates* of the solstices and equinoxes. But how is the point in question defined? Does Theon mean the tropical and equinoctial points and other points of the ecliptic defined in fixed relation to them?

The recently published papyrus text *PFouad* inv. 167 A provides unexpected illumination on the passage in Theon.[61] The text explains, apparently for the benefit of astrologers, how to calculate the Sun's longitude for a given date using a set of astronomical tables that is not preserved in the papyrus. Part of a worked example for a date in AD 130 is preserved, so that the date of composition was roughly contemporary with Theon, though the copy in the papyrus is likely to have been made some decades later, perhaps in the early third century. As was the case with Theon and *POxy astron.* 4174a, the solar tables used in *PFouad* inv. 167 A and the theory behind them assumed three distinct kinds of solar year and three associated mean motions, but their ostensible meanings are different. One year, whose name is not legible though it is characterized as "uniform" (ὁμαλός), is simply 365 $^1/_4$ days; it is not clear what astronomical meaning was ascribed to it. Another, called "from a turning" (ἀπὸ τροπῆς) and thus meant as a tropical year, is about $^1/_{300}$ days shorter than 365 $^1/_4$ days. The third, called "from a point" (ἀπὸ σημείου), is about $^1/_{100}$ days longer than 365 $^1/_4$ days; this must be meant as a sidereal year, though the text as preserved makes no explicit reference to fixed stars.[62] For the author of this text, a "point" was a sidereally defined point of the ecliptic. His precession theory obviously derives from Hipparchos, who is cited by name in the papyrus, though the precise parameters are not the same as in Ptolemy's version of the theory (*Almagest* 3.1 and 7.2–3).

Theon, however, shows no awareness of precession, so for him "point" could indifferently mean a sidereally or tropically defined point. He probably picked up the terminology for the definitions of his three kinds of year from the same source that gave him the theory of distinct longitudinal, latitudinal, and anomalistic years. Whoever was the originator of this theory obviously did not believe that the tropical and sidereal years had different lengths, but his conflation of expressions that designated distinct tropical and sidereal frames of

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61 Fournet and Tihon (2014).

62 For further discussion of the "from a point" terminology see Fournet and Tihon (2014): 111–114. The copyist of the papyrus (or possibly the text's author) mixed up the names of the different years, so that one has to interchange either the names or the year lengths given in recto lines 4–5 and 7. Additionally, the year lengths given in the explanatory text are slightly different from the values implied by the mean motion tables, apparently because the tables were designed to yield round values for the mean motions over a numerologically determined long period of 37500 Egyptian calendar years.

reference in the theory behind *PFouad* inv. 267 A might be an indication that he was not ignorant of Hipparchos's precession theory but rather rejected it.

According to the solar theory Theon is summarizing, the Sun's periods in longitude and in latitude are not strictly speaking constants because they are different in length from the period in anomaly, which by definition *is* a constant. Hence their stated lengths ought to be understood as mean values.

H173.3–4 *with it (i.e. the Sun) being restituted by a four-year-interval to the same point of length at the same hour*: That is, the smallest integer multiple of the periodicity is four times 365 $^1/_4$ days (2922 days). Hence solstices or equinoxes of the same kind will repeat at the same time of day after this interval. In principle this fact was observable, as can be seen from the equinox observations of Hipparchus cited by Ptolemy in *Almagest* 3.1, though these also included some discrepant times.

H173.6–7 *and because of this smallest in the appearance of size and slowest with respect to the motion towards the trailing (stars)*: Assuming the Hipparchian solar eccentricity ($^1/_{24}$ of the radius of the eccenter in an eccentric hypothesis), the apparent diameter of the Sun, as well as its apparent rate of eastward motion, should vary by about ±4% relative to the mean. It would of course have been a practical impossibility to observe to within a fraction of a day the moments when the Sun attained its maximum or minimum apparent size and speed, so these are not really empirical confirmations of the periods.

H173.13–14 *so that the shadows of the same gnomons are seen as again equal*: This is incorrect. For simplicity, we can consider the case of gnomon shadows measured at noon, which depend on the observer's latitude and the Sun's declination. According to Theon's solar theory, the solar declination has two components: the latitude of the Sun, and the declination of the point of the ecliptic corresponding to the Sun's longitude. After eight latitudinal periods of 365 $^1/_8$ days (i.e. 2921 days), the Sun should return to its initial latitude, but since this is one day short of eight longitudinal periods, the declination of the point of the ecliptic corresponding to the Sun's longitude will have changed – by as much as $^2/_5$° if the observations are made near one of the equinoxes.

H174.12–15 *the Moon's epicycle (appears) to be borne faster on the concentric (circle) and to fall behind on the circle of the zodiacal signs than (the Moon) itself (appears) to make the circuit of the epicycle*: In other words, the Moon's mean motion in longitude is faster than its mean motion in anomaly. This is correct, but does not in itself account for the Moon's never exhibiting stationary points or retrogradations.

Theon in fact, and apparently Adrastos as well, had a poor understanding of the conditions under which an epicyclic hypothesis (or the counterpart eccentric hypothesis) generates retrogradations. At H190.1–191.7 Theon illustrates retrogradation using a diagram in which the planet is seen to travel retrograde when traveling along the arc of the epicycle that is farthest from the Earth and bounded by the tangent lines from the Earth to the epicycle, which could only be correct if the epicycle was itself stationary. Interestingly, Calcidius (Waszink [1962]: 136–138) gives the same defective demonstration but follows it with a different version according to the "mathematicians", in which the arc of the epicycle on which the planet is seen as travelling retrograde is still delimited by the tangents from the Earth, but this time it is the arc closest to the Earth. All this is likely to derive from Adrastos. According to Calcidius, the philosophers prefer the version in which the planet is retrograde when furthest from the Earth because this makes the planet's direction of revolution on its epicycle from east to west (as in the epicyclic hypotheses for the Sun and Moon), thus conforming to a principle that none of the celestial motions should be contrary to the prevailing east to west daily rotation of the heavens.[63] Calcidius does not say why the "mathematicians" posit an opposite direction of revolution for the planets. In the cases of Venus and Mercury, it would have been obvious to an astronomer that the retrogradations occur when the planet is closest to the Earth because they fall within intervals delimited by greatest elongations from the Sun that are distinctly shorter than half a synodic period.[64] In Mars's case (as well as that of Venus), when one takes into account the effect of the epicycle's own revolution around the Earth, which Theon and Calcidius entirely neglect, the revolution of the planet on its epicycle *must* be from west to east to generate retrogradations at all.[65]

H175.1–16 Here Theon describes a simple epicyclic hypothesis to fit the general case of any of the seven "wanderers" (cf. section 7.2).

The diagram for this passage (here placed following H175.16) appears in *Marc. gr.* 303 in the left margin of f. 13v; Hiller's counterpart is at H174. The manuscript version has the epicycle EZHK slightly off its correct center, namely point M, which is missing its label, and the epicycle touches circle ΑΒΓΔ near A so that A and E are indistinguishable; the label of point Λ is also missing.

63 The west-to-east revolution of the epicycles around the Earth relative to the stars has to be understood as really being an east-to-west revolution around the Earth at a rate slightly slower than that of the fixed stars.

64 Neugebauer (1975): 801.

65 Neugebauer (1975): 807–808.

Hiller's version of this diagram is basically the same except that he draws a much smaller epicycle. The elements of the diagram are a subset of those in the diagram (H158, correcting the very inaccurately executed version on f. 12v of *Marc. gr.* 303) that was previously used to show how an epicyclic hypothesis for the Sun yields the unequal seasons, and the corresponding points in the two diagrams are lettered identically.

The frame of reference for the motion of the epicycle around the Earth is sidereal, so that the motion is stated to be in the opposite direction to the daily revolution of the heavens (cf. section 7.3). In contrast to his later discussion of planetary retrogradations discussed above in the note to H174.12–14, Theon here states that while the Sun and Moon revolve about their epicycles in the east-to-west direction of the daily revolution, the five planets revolve in the opposite direction, in other words the "correct" scheme according to mathematical astronomy. This passage and the one that follows concerning the eccentric alternative have no parallels in Calcidius, and one might wonder whether, notwithstanding Theon's after-the-fact statement (H177.9–11) that the preceding material was from Adrastos, he was actually drawing here on a more technically assured source to fill out what in Adrastos's commentary was only a brief assertion that the things demonstrated earlier for the Sun also apply *mutatis mutandis* to the Moon and planets.

H175.1–2 *It is obvious that it makes no difference for saving the appearances*: Cf. section 7.4. The distinction Theon draws is between the conception of the visible bodies of the Sun, Moon, and planets as things that move in their own right along certain circular paths and that of the circles as the agents of the motions, carrying the visible bodies fixed upon themselves. This anticipates Theon's later description (H181.12–188.24) of systems of three-dimensional spherical shells and solid spheres that he believes are the physical reality from which the bare geometrical circles of the epicyclic and eccentric hypotheses arise as "by happenstance" consequences.

H175.17–177.8 The generalized eccentric hypothesis applicable to all seven "wanderers".

The diagram for this passage and the next (here placed following 177.21) appears in *Marc. gr.* 303 in the lower margin of f. 13v. A superfluous epicycle has been drawn in approximately the same location as in the first diagram, touching the eccenter circle ΕΛΥΚ at Ε; the label of point Κ is misplaced to be near the lower intersection of this epicycle and line ΑΓ. Hiller's version of the diagram (H175) is quite different, since he draws circle ΑΒΓΔ, which represents the ecliptic, as having nearly the same radius as ΕΛΥΞ so that they intersect at Λ and Ξ, and he omits the labels of points A, B, Γ, and Δ. The elements of the diagram here (H175) only partly match those of previous diagrams referring to the eccentric hypothesis.

H176.1–21 The extended description of the solar case seems superfluous since an eccentric hypothesis for the Sun has already been discussed earlier. It is also strange that the small circle ΚΡΠ in the diagram serves different functions here and in the treatment of the hypothesis for the Moon and planets. The diagram in general is supposed to be drawn as fixed in a sidereal frame of reference, and the center of the Sun's eccenter therefore ought to have a fixed position at Κ. Yet Theon states that ΚΡΠ is the path traced by the Sun's center in the course of the daily revolution of the heavens, which would only make sense if the diagram had a "terrestrially" fixed frame of reference. Has Theon inserted this pointless interpretation of the circle because he incorrectly assumed that it has to have *some* meaning for the solar case?

H176.11–12 *at the $5^1/_2$th degree of the Twins*: This is the "Hipparchian" longitude of the solar apogee, which has already been given at H157.5–6.

H176.16 *under the Twins*: "Under" (ὑπό) in the geocentric sense, i.e. the Sun's path is closer to the Earth than are the stars of the zodiac.

H177.3 *in the opposite sense to the whole*: That is, the center of the eccenter, and thus the apsidal line of the eccentric hypothesis, increases uniformly in longitude (cf. section 7.3). This would be correct for a simple eccentric hypothesis in the case of the Moon as well as the five planets (and indeed for the Sun if one accepts Theon's scheme of solar periodicities).

H177.4–8 Theon does not specify the sense of revolution of the body on the eccenter. If it is considered according to a sidereal frame of reference, the motion of the body must in all cases be in the direction of increasing longitude. If, however, the frame of reference is geocentric (as it always is for the revolution of bodies on epicycles) it will be in the direction of increasing longitude for the Moon but in the direction of *decreasing* longitude for the five planets.

H177.9 *he expounds these things at greater length*: This seems to imply that much or all of the foregoing material on the hypotheses came from Adrastos's commentary; but see the note to H172.16 and H175.1–16 for doubts about the origin of certain passages. It is not clear whether "at greater length" (ἐπὶ πλέον) means that Adrastos had still more to say on the relation of the hypotheses or just that this was an exceptionally detailed treatment of a topic.

H177.13–15 *having observed them for long time-intervals because of the natural suitability of their country – (I mean) the Babylonians and Chaldeans and Egyptians*: Unless the text has suffered corruption, Theon makes an abrupt and unexpected transition here. He has just (H177.11–13) characterized the "mathematicians" in the expected way, as only concerning themselves with phenomena and "the motions… that occur by happenstance" (by which he means the bare circles of the eccentric and epicyclic hypotheses), in implied contrast to the philosophers who go deeper into physical causation. He has never said who these "mathematicians" are, and the reader would probably assume he has been speaking all along about scholars in the Greek-speaking world. But the additional statement that they lived in lands specially suited to astronomical observation and hence made observations over long spans of time does not fit the Greeks, and almost as an afterthought Theon specifies that he means the Babylonians and Chaldeans and Egyptians.

Although the great antiquity of observations from the Near East was a commonplace by Theon's time, it is likely that he was specifically recalling Aristotle, *De Caelo* 2.12, "the Egyptians and Babylonians who of old observed over numerous years", as well as the Platonic *Epinomis* 987a, "ancient practice trained the first who understood these things (*scil.* astronomy) on account of the fineness of the summer season that Egypt and Syria have to a great extent, always beholding all the stars clearly, so to speak".

Theon's addition of the "Chaldeans" to the list of ancient observers reflects a Greco-Roman perception of the practitioners of the astral sciences in the Near East that became prevalent in Hellenistic and Roman times. While some authors (e.g. Strabo 16.1.6 and Ptolemy, *Geography* 5.20) mention a people or tribe called Χαλδαῖοι who inhabited a southern district of Babylonia, the name was more frequently taken to apply to the class of temple-based Babylonian scholars who excelled in the astral sciences as well as other forms of divination, so in speaking of "the Babylonians and Chaldeans" Theon is referring by a more generic and a more specific name to the same people. Thus, Strabo (16.1.6 again) writes that a "dwelling place" was reserved in Babylon (or in Babylonia, depending on the resolution of a corrupt word in the manuscript tradition) "for the philosophers of the land, the ones called Chaldaioi, who are for the most part concerned with astronomy/astrology (ἀστρονομία)", while Pliny the Elder (6.123) designates the cities of Babylon, Sippar (*Hippareni*), and Uruk (*Orcheni*) as *Chaldaeorum doctrina*, apparently meaning that they were sites of schools of Chaldean learning. Diodoros (2.29–31) has a remarkable extended account of the Chaldeans in which he says that within the Babylonian state structure they occupy a role comparable to that of priests in Egypt, involving both cults of the gods and practicing philosophy (φιλοσοφεῖν), "having the greatest reputation in astronomy/astrology (ἀστρολογία)". Many things that Diodoros writes about the Chaldeans' training, divinatory practices, and astronomical and astrological beliefs agree with what we know from cuneiform sources about the Babylonian practitioners of the astral sciences, but mixed up with these statements are some that are odder and of questionable accuracy, for example a doctrine concerning thirty zodiacal stars called "counsellor gods" (βουλαῖοι θεοί) that seems to be influenced by the Egyptian decans. Elsewhere (1.28 and 1.81), Diodoros reports that the Egyptians claimed that the Chaldeans originated in Egypt and were led of old to Babylonia by Belos (i.e. the Babylonian god Marduk), taking the learning of the Egyptians with them, a story that illustrates how difficult it must have been for Greek and Roman authors to sort out the varied claims of antiquity and originality associated with the Babylonians and Egyptians.

H177.16–18 *to make judgment with respect to the things found before and to forecast with respect to things going to happen*: This may mean simply that the Babylonians and Chaldeans and Egyptians sought methods of making both retrospective and prospective predictions of astronomical phenomena that could be compared with observations, but the passage is also suggestive of astrological prognostication.

H177.18–20 "Numerical methods" would be a very appropriate characterization of the Babylonian "ACT" algorithms for calculating lunisolar and planetary phenomena and positions, but it is not at all clear what Theon has in mind when he attributes "graphical" (γραμμικαί) methods to the Egyptians. Pictoral representation of the heavens was an integral part of Egyptian astronomy from at least as early as the New Kingdom (cf. the so-called "Book of Nut", more properly "Fundamentals of the Course of the Stars"), and in Hellenistic and Roman Egypt images of the decans and zodiac were widespread.[66] But it is difficult to connect these representations with the kind of prediction of past and future that Theon is writing about. On the other hand, the term γραμμικαὶ μέθοδοι, in the sense of "methods employing lines" or "geometrical methods", would be applicable to eccentric and epicyclic modeling, and it is conceivable that Theon ascribed this approach to the Egyptians both to produce a neat counterpart to the Babylonians and to help lead the way back to the Greeks.

H177.22–23 *and this is the very thing that those among the Greeks who engaged in astronomy tried to do*: "this" apparently refers to the consideration of nature

66 Von Lieven (2007); Neugebauer and Parker (1969).

that Theon has said was lacking in the efforts of the Chaldeans and Egyptians; that is, he is eliding over the existence of Greek “mathematicians” in order to make the claim that the philosophical approach was characteristically Greek.
H178.1 *just as Plato discloses in the Epinomion*: the allusion is to *Epinomis* 987d–e, “let us assume that whatever the Greeks take over from the barbarians, they work this in the end into something finer”. The promised quotation, however, does not appear in Theon’s work as we have it.

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Figures

Fig. 1–3: Alexander Jones.