PLINY ON THE PLANETARY CYCLES

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ALTHOUGH PLINY DEVOTES BOOK 2 of the *Naturalis historia* to the heavens, he makes exasperating reading for anyone who hopes to learn from him about the character of astronomy during the poorly known interval between Hipparchus and Ptolemy. He consulted and took notes on numerous writings on astronomy that have not otherwise come down to us, but he possessed neither the scientific competence necessary to understand the texts nor an adequate Latin technical vocabulary to make them intelligible to his reader.[1] Yet Pliny's garbled testimony sometimes becomes intelligible when it is combined with the other fragmentary evidence for the astronomy of this period. In this article I try to recover the sense of one particularly baffling passage and identify the character of Pliny's source for it, through comparison with recently discovered contemporary Greek astronomical texts. The comparison turns out to be profitable in both directions, for not only do the Greek texts clarify Pliny, but, once explicated, Pliny in turn helps to fill in certain gaps in the more technical documentation available in Greek.

The passage in question is part of Pliny's extended discussion of the motions of the five planets. Pliny begins this section with a review of the planetary phases, that is, the cycle of conspicuously observable events in the revolutions of the planets relative to the sun and earth that were the chief concern of Babylonian observational and predictive astronomy, and remained prominent in the Greek science. First, (2.59–60) Pliny takes up the cycle of phases of the three outer planets (Saturn, Jupiter, Mars) in relation to their elongations from the sun. Starting from conjunction with the sun, when the planet is of course invisible, an outer planet makes its first morning appearance (Γ), in Neugebauer's conventional "Greek letter" notation; cf. Table 1)[2] at "no more than" 11° elongation trailing the sun (in order of longitudes, not risings), then its first or "morning" station (Φ) at 120° elongation (which, he points out, is the astrological trine aspect), its evening, or acronychal, rising (Θ) at 180° elongation (i.e., opposition to the sun), and its second or "evening" station (Ψ) at 120° elongation ahead

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[1]The summary of contents and sources of Book 2 in *HN* 1 lists perhaps a dozen "foreign," mostly Greek, authors whom Pliny may have digested for astronomical information. Needless to say, it is a hopeless task to correlate these names with most specific passages in Book 2.

[2]O. Neugebauer, *A History of Ancient Mathematical Astronomy* (Berlin 1975) 386–387 (this work will hereafter be cited as Neugebauer, *HAMA*).

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of the sun, finally making its evening setting (Ω) at 12° elongation. Mars is said to have two additional "satellite phases" at 90° elongation, called the first and second *nonagenarii*.[3] According to Pliny, all the phases are caused by the influence of the sun's "rays" (*radii*, probably representing ἀκτῖνες), in the case of Γ and Ω in an optical sense, for the others by some sort of physical influence.

Γ	First visibility in morning
Φ	First (morning) stationary point
Θ	Acronychal rising (rising at sunset)
Ψ	Second (evening) stationary point
Ω	Last visibility in evening

Table 1. Phases of the Outer Planets

The phases of an inner planet (Venus or Mercury) are the next topic (2.61; cf. Table 2). These planets begin their synodic cycle after inferior conjunction with first morning rising (Γ) at the same elongation of 11° behind the sun. Then, after the greatest elongation is reached, the morning "setting" (Σ) occurs when the planet returns to 11° elongation. After a period of invisibility during which superior conjunction takes place and the planet passes the sun, its first evening "rising" (Ξ) takes place at the same elongation ahead of the sun; this is followed by the evening setting (Ω). Pliny adds that Venus has two stationary points, morning station (Φ) and evening station (Ψ), allegedly coinciding with the planet's greatest elongations, while Mercury's stations are too close (to conjunction?) to be perceived.

Γ	First visibility as morning star
Φ	Morning stationary point
Σ	Last visibility as morning star
Ξ	First visibility as evening star
Ψ	Evening stationary point
Ω	Last visibility as evening star

Table 2. Phases of the Inner Planets

Pliny thereupon (2.62–65) sets out "causes" which are supposed to explain the foregoing phenomena. The first is that the planets have circles

[3]The *nonagenarii* (which are also mentioned by other classical authors) were explained by Neugebauer, *HAMA* 792: they mark the two moments roughly ninety days before and after Θ when Mars is at the same longitude as at Θ. So far as we know, there was nothing corresponding to these "phases" in Babylonian astronomy.

called *apsides*. What Pliny means by this term is far from perspicuous, but since he specifies zodiacal signs for the *apsides altissimae* that correspond more or less to the longitudes of the planetary apogees, the most plausible interpretation is that the *apsides* are the "deferent" circles not concentric with the earth, on which the planetary epicycles are borne in the eccentre-and-epicycle planetary model standard in Greek astronomy since Hipparchus.[4] These eccentres, of course, do not explain the existence of synodic cycles (that is the function of the epicycle), but only their variations through the ecliptic—which Pliny has not mentioned! One also looks in vain for some reference to epicycles travelling on these deferents. Still worse, he next lists, as *altera sublimitatium causa*, the astrological "exaltations" (ὑψώματα) of the planets, which have nothing to do with their variable motions. Finally, he suggests (*tertia altitudinum ratio*) that the planets rise and descend in the heavens to produce an optical appearance of varying motions.

After this (2.66–67) Pliny specifies the range of degrees north or south of the ecliptic that the sun, moon, and planets attain in their latitudinal motions. He alleges, rather obscurely, that certain writers have wrongly believed that the latitudinal motions are correlated with the ascents and descents of his *tertia ratio*. To refute this notion, he writes, "demands the opening of a great subtlety embracing all these causes." What follows (2.68–76) is an extended description of the planets' motions in "altitude" (*altitudo*) and latitude through their synodic cycles, interspersed with physical explanations in terms of the action of the sun's rays on the planets. For the outer planets, the physical theory is that a ray from the sun falls upon the planet at its two trine aspects (i.e., 120° elongation from the sun), driving it directly away from the earth at Φ and towards the earth at Ψ. Consequently the planet seems to be stationary at these points and appears smallest at Θ.[5] For the inner planets there is no talk of solar rays, but these planets are said to have *apsides* (possibly now meaning epicycles) that wobble back and forth below the sun in such a way that the sun is never allowed to fall outside them as seen from the earth. The inner planets are described as moving slowest when near the earth, contrary to the outer planets.

To round off the topic of the planetary motions, we are given a selection of curious or paradoxical "facts" concerning the phases (2.77–78). Many of these (e.g., the claims that Mars never is stationary at trine aspect with Jupiter, and seldom at 60° elongation) are false, and it is not easy to see how Pliny came by them. The discussion of the planets concludes (2.79–80)

[4]This sense of ἀψίς does not seem to occur in the known Greek texts.

[5]In fact the outer planets appear brightest at opposition. It is hard to see how Pliny could have been ignorant of this phenomenon, which was well known in Greek astronomy since about 300 B.C.

with speculations concerning the effect of their distance from the earth on their apparent colours.

That Pliny was combining, none too skilfully, several sources of divergent character is obvious; perhaps the blending is the original contribution that Pliny boasts of (2.62 and 71). The curious "heliodynamic" theory of the planets' anomalistic motion was apparently most to Pliny's taste, but it is not wholly his own invention; similar notions appear in Vitruvius and elsewhere, and presumably descend from Hellenistic physical speculations.[6] Pliny's mistaken belief that the outer planets are furthest from the earth at Θ, and closest between Ω and Γ seems to be connected with this physical theory, although it is paralleled by the description of the planets' motions according to epicyclic models in the second-century astrological papyrus *PMich* 149.[7] From a different, and ultimately incompatible, tradition of Greek mathematical astronomy come the cinematic geometrical models represented by Pliny's *apsides.* The scheme associating planetary phases with specific elongations from the sun also pertains to mathematical astronomy, but of another kind not based on geometrical models: such elongation schemes had their origin in Babylonian astronomy of the Achaemenid and Seleucid periods, and are attested in classical documents and in medieval Indian texts dependent on Greek sources.[8]

Interwoven with these three strands is a fourth, the account of the planets' changing "altitude" and latitude through the synodic cycles in 2.68–76. I quote and translate the relevant passages below:[9]

[68] *convenit stellas in occasu vespertino proximas esse terrae et altitudine et latitudine, exortusque matutinos in initio cuiusque fieri, stationes in mediis latitudinum articulis, quae vocant ecliptica. perinde confessum est motum augeri, quamdiu in vicino sint terrae; cum abscedant in altitudinem, minui. quae ratio*

[6] Vitruvius 9.1.6–13. Similar material in Martianus Capella 879–887 seems to be pilfered from Pliny. No adequate study of these texts has ever been made; but see the interesting posthumous fragment by Schiaparelli, "Di un' antica ipotesi eliodinamica sul movimento dei pianeti," in G. Schiaparelli, *Scritti sulla storia della astronomia antica, parte seconda—scritti inediti* 3 (Bologna 1927) 287–298, and W. Kroll, "Plinius und die Chaldäer," *Hermes* 65 (1930) 1–13, who argues (unconvincingly) for a Babylonian origin of the heliodynamic theory.

[7] A. Aaboe, "On a Greek Qualitative Planetary Model of the Epicyclic Variety," *Centaurus* 10 (1965) 213–231.

[8] A Babylonian elongation scheme for Mars was identified by B. L. van der Waerden, "Babylonische Planetenrechnung," *Vierteljahrsschrift der Naturforschenden Gesellschaft in Zürich* 102 (1957) 39–60, at 52. For analogous parameters in Greek and Latin sources, see Neugebauer, *HAMA* 411, n. 11 and 830–833. The sixth-century Sanskrit *Pañcasiddhāntikā*, 17.64–80, gives full elongation schemes for all five planets; see O. Neugebauer and D. Pingree, *The* Pañcasiddhāntikā *of Varāhamihira* 2 (Copenhagen 1970–1971) 126–128.

[9] I have used the text of J. Beaujeu (Paris 1950, Belles Lettres). There are no textual problems of any importance in the passages quoted.

lunae maxime sublimitatibus adprobatur. aeque non est dubium in exortibus matutinis etiamnum augeri atque a stationibus primis tris superiores deminuere usque ad stationes secundas. [69] *quae cum ita sint, manifestum erit ab exortu matutino latitudines scandi, quoniam in eo primum habitu incipiat parcius adici motus; in stationibus vero primis et altitudinem subiri, quoniam tum primum incipiant detrahi numeri stellaeque retroire* .... [71] *ab exortu vespertino latitudo descenditur, parcius iam se minuente motu, non tamen ante stationes secundas augente, cum et altitudo descenditur, superveniente ab alio latere radio eademque vi rursus ad terras deprimente, qua sustulerat in caelum e priore triquetro. tantum interest, subeant radii an superveniant, multoque eadem magis in vespertino occasu accidunt. haec est superiorum stellarum ratio; difficilior reliquarum et a nullo ante nos reddita* ....

[75] *incipit autem ab exortu matutino latitudinem scandere, altitudinem vero ac solem insequi a statione matutina, ocissima in occasu matutino et altissima, degredi autem latitudine motumque minuere ab exortu vespertino, retro quidem ire simulque altitudine degredi a statione vespertina. Mercurii rursus stella utroque modo scandere ab exortu matutino, degredi vero latitudine a vespertino, consecutoque sole ad quindecim partium intervallum consistit quadriduo prope inmobilis.* [76] *mox* [*ab*] *altitudine descendit retroque graditur ab occasu vespertino usque ad exortum matutinum. tantumque haec et luna totidem diebus, quot subiere, descendunt. Veneris quindecies pluribus subit, rursus Saturni et Iovis duplicato degrediuntur, Martis etiam quadruplicato. tanta est naturae varietas, sed ratio evidens: nam quae in vaporem solis nituntur, etiam descendunt aegre.*

[68] It is accepted that the planets are nearest the earth in altitude and latitude at evening setting [Ω], and that the morning risings [Γ] are at the beginning of both [altitude and latitude], and the stations [Φ and Ψ] are between the latitudinal nodes, which they call "ecliptics." Moreover, it is granted that the motion increases as long as they are in the neighbourhood of the earth; and when they depart in altitude, [the motion] decreases. This account is especially confirmed by the moon's apogees. There is likewise no doubt that [the motion] still increases at the morning risings [Γ] and the three superior [planets] diminish [the motion] from the first stations [Φ] right to the second stations [Ψ]. [69] Consequently it is obvious that the latitudes rise from the morning rising [Γ] since in that situation the motion first begins to be added less; and at the first stations [Φ] the altitude too ascends, since it is then that the numbers first begin to be subtracted and the stars to retrogress .... [71] From the evening rising [Θ] the latitude descends, while the motion is now decreasing less, but not increasing before the second stations [Ψ], when the altitude too descends because the ray comes down upon [the planet] from the other side and presses [it] back down to the earth with the same force by which it raised [it] up into the heavens starting with the previous trine aspect. It makes this much difference whether the rays go up or come down, and the same things occur much more at the evening setting [Ω]. This is the account for the superior planets; that for the rest is more difficult, and has been given by no one before us ....

[75] [Venus] begins to ascend in latitude from morning rising [Γ], but [to ascend] in altitude and follow the sun from the morning station [Φ]; it is swiftest and highest at morning setting [Σ], and [begins] to decline in latitude and to decrease its motion from evening rising [Ξ], and to retrogress and at the same time decline in altitude from evening station [Ψ]. Again, the planet Mercury [begins] to ascend in both ways from morning rising [Γ], and to decrease in latitude from evening [rising, J], and after following the sun it stands almost stationary at an interval of fifteen degrees for four days. [76] Soon it descends in [deleting *ab*] altitude and retrogresses from evening setting [Ω] right to morning rising [Γ]. And only this [planet] and the moon descend for the same number of days as they ascend. Venus ascends for fifteen times more [days], while on the contrary Saturn and Jupiter descend twice [as long as they ascend], and Mars even four times [as long]. So great is the variety of nature, but the reason is clear: for those [planets] that strive in the sun's vapour even descend with difficulty.

Interval	Altitude	Latitude	Motion
Γ to Φ		ascends	added less
Φ to Θ	ascends		retrograde
Θ to Ψ		descends	subtracted less
Ψ to Ω	descends		increases

Table 3. Outer Planets (2.69–71)

Interval	Altitude	Latitude	Motion
Γ to Φ		ascends	
Φ to Σ	ascends		follows sun
Σ to Ξ	highest		swiftest
Ξ to Ψ		descends	decreases
Ψ to Ω	descends		retrograde

Table 4. Venus (2.75)

Interval	Altitude	Latitude	Motion
Γ to Σ	ascends	ascends	
Σ to Ξ			
Ξ to Ω		descends	
Ω to Γ	descends		retrograde

Table 5. Mercury (2.75–76)

The patterns of motion describe the vicissitudes of three quantities: motion, altitude, and latitude (see Tables 3–5). "Motion" evidently refers to the planet's day-to-day progress in longitude, whether direct or retrograde, slow or fast. At first view, "altitude" would seem to signify simply the distance of the planet from the earth, and "latitude" deviation of the planet north and south of the ecliptic. Commentators have not failed to notice that Pliny's schemes, so interpreted, make no astronomical sense.[10] Granted that Pliny believes that the outer planets are furthest from the earth at Θ when they are in fact nearest, and that they are nearest at conjunction when they are in fact furthest, why should the altitude start to ascend only at Φ, and begin to descend only at Ψ? Why are there intervals during which, apparently, the altitude does not change at all? And, what is more serious, the planets' latitudinal movements are primarily determined by their longitudes, so that it would be flatly wrong to make them move north or south always at the same stages of their synodic cycles.

I do not think that Pliny himself can be acquitted of gross ignorance of simple astronomical facts; the basic terminology of the science can have had little meaning from someone who could write of a planet as being "nearest the earth ... in latitude"![11] Still, it is hardly plausible that Pliny made these elaborate schemes up entirely from his imagination, especially since his physical theory makes no attempt to account for the latitudinal motion. We are therefore confronted with the problem of recovering the original sense of the schemes before Pliny's uncomprehending misapplication of them.

The first element of the solution was Neugebauer's recognition that *altitudo* refers not only to general distance from the earth, but specifically to the variation of a planet's distance caused by its motion on an epicycle or eccentre.[12] The usual term for this quantity in Greek astronomy before Ptolemy is βάθος, "depth"; Neugebauer points out that *PMich* 149 uses ὕψος in the same sense. Either word could be rendered by Pliny's *altitudo*. The terminology suggests that Pliny's source had to do with mathematical astronomy and geometrical models.

[10]Beaujeu (above, n. 9) 146–166 "explicates" these chapters at considerable length, only to refute them (not without such expressions of impatience as "Accessoire bizarre du bric-à-brac astrologique!"). J. B. Delambre, *Histoire de l'astronomie ancienne* 1 (Paris 1817) 284–287, more circumspectly refused to impose a meaning where he could find no sense. The commentary by D. J. Campbell, *C. Plini Secundi Naturalis historiae liber secundus* (Aberdeen 1942, Aberdeen University Studies 118), offers no help on this passage.

[11]Cf. the just remarks of Delambre (above, n. 10) 284: "Il parle ensuite des latitudes en termes encore plus extraordinaires, ce qui n'empêche pas d'apercevoir des bévues singulières qui prouvent que Pline ne comprenait pas ce qu'il se donne tant de peine à défigurer."

[12]Neugebauer, *HAMA* 802. Campbell (above, n. 10) 61 had already identified Pliny's *altitudo* with motion κατὰ βάθος.

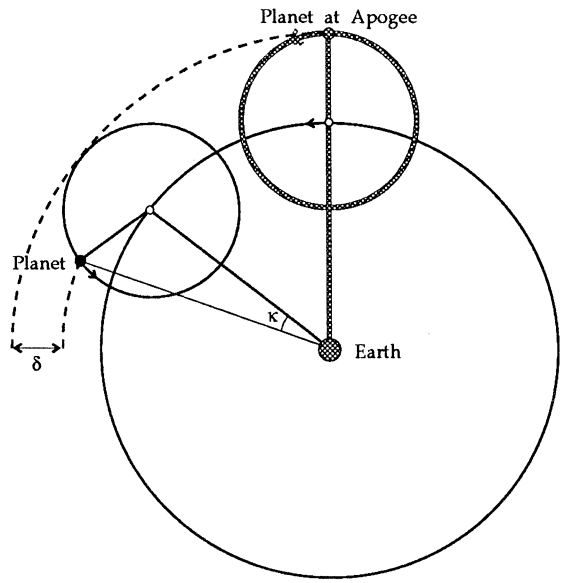

Fig. 1. Effect of "depth" on longitude in an epicyclic model.

The assumption of an epicyclic or eccentric model for a heavenly body (sun, moon, or planet) leads immediately to the realization that the body's longitude and latitude are influenced by its "depth." This can be seen clearly from a simple epicyclic model (cf. Fig. 1), in which the centre of the epicycle revolves with uniform speed about a deferent circle concentric with the earth, while the visible body revolves uniformly about the epicycle. The motion in "depth" (δ) is then merely an aspect of its motion on the epicycle, and while it moves from its closest to its furthest distance from the earth or *vice versa*, it must also move ahead or behind its "mean position," which is the centre of the epicycle as seen from the earth (in Fig. 1, the difference is κ). Consequently the motion in "depth" can be said to cause an anomaly in the body's longitude (i.e., it is not seen from the earth as travelling with uniform speed). If the model is assumed to lie entirely in a plane inclined to the plane of the ecliptic (which is appropriate for the moon; cf. Fig. 2), then the back-and-forth movement of the visible body on the epicycle will also give it a deviation β from the ecliptic different from that of the epicycle's centre ($\bar{\beta}$), so we can say that the "depth" is also the cause of an anomaly in latitude. In a model appropriate for a planet (cf. Fig. 3), the deferent circle and the epicycle are not in the same plane, and the position of the planet on the epicycle has a different effect; now the largest component of

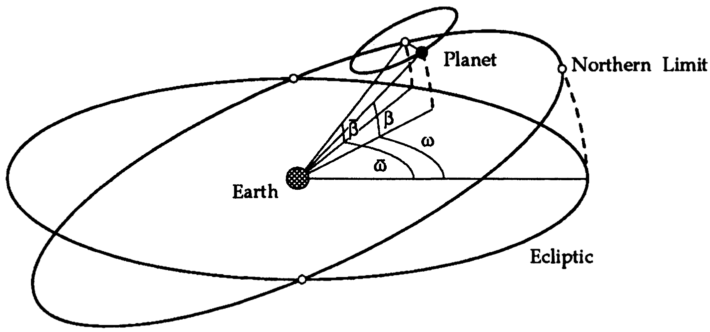

Fig. 2. Effect of "depth" on latitude in a single-plane epicyclic model.

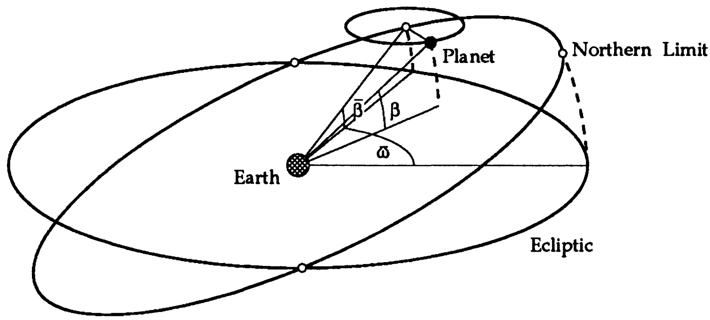

Fig. 3. Effect of "depth" on latitude in a two-plane epicyclic model.

the difference between the latitude of the planet and the "mean" latitude of the epicycle's centre results directly from the planet's "depth," i.e., its alternate motion towards and away from the earth.

It is scarcely necessary to prove that Greek astronomers were conscious of the interplay of "depth," longitude, and latitude. Recently, however, a text on this topic has come to light that has interesting parallels with Pliny's schemes.[13] This is an anonymous fragment of a commentary (written about A.D. 213) on Ptolemy's *Handy Tables*, in which (§§64–86) we find an extensive quotation from a lost treatise on lunar theory by Apollinarius, an astronomer whose career probably fell in the early second century. This text is relevant for understanding Pliny, and not just in that Apollinarius

[13] A. Jones, *Ptolemy's First Commentator* (Philadelphia 1990, *TAPS* 80.7). The text and its quotation from Apollinarius have been known since its publication in *Catalogus codicum astrologorum Graecorum* 8.2 (Brussels 1911), but this edition was so bad that intelligent discussion of the fragment was practically impossible.

describes the cycle of effects of the moon's motion in "depth" on its longitudinal and latitudinal motion through an anomalistic period. Apollinarius also consistently uses the term πλάτος, "latitude," to signify not the angle of north/south inclination itself between the moon and the ecliptic, but rather the argument of latitude, that is, the elongation of the moon *in longitude* with respect to the northern limit of the moon's deferent, where it is furthest from the plane of the ecliptic (cf. Fig. 2). This is an unusual usage, at least if we take Ptolemy's terminology as standard, but its currency is also attested by an important third-century papyrus concerning pre-Ptolemaic lunar tables (*PRylands* 27); perhaps it has some relevance also for Pliny.[14] Using "latitude" in the sense of "argument of latitude," Apollinarius can speak of the "depth" as affecting the "latitude" in exactly the same way as it affects the longitude: when the moon is ahead of its mean position, the "depth" is "adding to" both longitude and latitude, and when the moon lags, the "depth" is "subtracting from" both quantities. Thus the increase and decrease in "latitude" are legitimately correlated with the stages of the anomalistic cycle.

Apollinarius' lost book on the lunar motions in all probability had some connection with the tables for predicting the moon's positions that he is known to have published. From the astrologer Vettius Valens (late second century) we know not only of the existence of these tables, but also that they were of a format that is almost entirely reconstructible from papyri dating from the second and third centuries of our era: *PRylands* 27 (mentioned already above), and the second-century *PLund* Inv. 35a, and *PSI* 1493.[15] The central component of the tables was a "template" table

[14] O. Neugebauer, "The Astronomical Treatise *P. Ryl.* 27," *KglDanskeVidenskSelsk, Hist-filolMedd* 32.2 (1949). Given the want of adequate lexicographical aids for Greek astronomical terminology, it is possible that there exist other instances of πλάτος meaning argument of latitude; it is not to be confused with expressions such as ἐποχὴ κατὰ πλάτος which unambiguously signify the argument of latitude in Ptolemy and elsewhere. I have not found secure examples of the equivalent use of *latitudo* in Latin authors other than Pliny either in my own reading or in A. Le Boeuffle, *Astronomie, Astrologie: Lexique Latin* (Paris 1987).

[15] Vettius Valens, *Anthologiae* 11.11, ed. D. Pingree (Leipzig 1986, Teubner) 339. For the reconstruction of the lunar scheme and its identification with Apollinarius' tables, see A. Jones, "The Development and Transmission of 248-Day Schemes for Lunar Motion in Ancient Astronomy," *Archive for History of Exact Sciences* 29 (1983) 1–36, especially 27–33. For *PLund* Inv 35a, see E. J. Knudtzon and O. Neugebauer, "Zwei astronomische Papyri," *Bulletin de la Société Royale des Lettres de Lund*, 1946–1947, II, 77–88. *PSI* 1492 and 1493 await publication in the long-delayed vol. 15 of the *Pubblicazioni della Società Italiana per la recerca dei papiri greci e latini in Egitto*. A partial transcription of *PSI* 1493 was given by Neugebauer, *HAMA* 822–823, and the contents were fully restored by Jones, "... 248-Day Schemes ...," 17–23. Lunar longitudes computed according to the scheme have now turned up in an unpublished papyrus ephemeris for A.D. 348, *POxy* inv. 67 6B.10/L(1)(a).

listing the moon's daily progress in longitude and argument of latitude through a period of anomaly; *PSI* 1493 is a fragment of such a template. The anomalistic variation in the longitudes and arguments of latitude in the template were not computed according to the correct trigonometric formula from a geometrical model, but approximated by a pattern of second-order arithmetical sequences (i.e., the differences between consecutive numerical entries increase or decrease by constant amounts). The arithmetical pattern derives, with modifications, from Babylonian astronomy.

Could Pliny have based his account of the synodic cycles on a text analogous to Apollinarius's, but concerned with planetary rather than lunar tables? That there were such planetary tables is confirmed by two papyri, *PSI* 1492 and the Demotic *PCarlsberg* 32 (both second century), which contain parts of templates respectively for Saturn's and Mercury's synodic cycles.[16] Like the lunar template, these tables use arithmetic sequences derived ultimately from Babylonian astronomy, although they apparently profess to represent the behaviour of geometrical models. Both templates begin and end with Γ, which may be the explanation of Pliny's otherwise cryptic assertion (2.68) that Γ is "at the beginning of both" altitude and latitude.

The pattern of arithmetical sequences representing Saturn's longitudinal motion in *PSI* 1492 is entirely reconstructible, and agrees perfectly with Pliny's description of the outer planets' "motion" in 2.68–71. In the template the daily motion is constant between Ω and Γ, and diminishes by constant differences from Γ to Φ. This is clearly what Pliny—or rather, Pliny's source—means by saying that at Γ "the motion first begins to be added less" (2.69). By Φ the daily motion has descended to zero, and now begins to ascend again by constant differences; but these numbers are to be subtracted from the running totals, because we have now begun the retrograde motion. The maximum retrograde motion is attained at Θ, after which the daily motion descends by the same constant differences back to zero at Ψ; hence "the motion is now decreasing less" (2.71). Pliny says nothing about the remaining intervals from Ψ to Ω (which in the template mirrors the pattern from Γ to Φ) and from Ω to Γ. As preserved, the papyrus template has no column for Saturn's argument of latitude, but Pliny's remarks fit the assumption that the argument of latitude was reckoned as the angle from the northern limit (either at a fixed longitude, or slowly and uniformly shifting) to the planet's true position, just

[16]For the intended publication of *PSI* 1492, above, n. 15. Again Neugebauer, *HAMA* 790–791, gives a transcription. The missing parts were reconstructed by A. Jones, "A Greek Saturn Table," *Centaurus* 27 (1984) 311–317, with corrections in A. Jones, "Models and Tables in Ancient Astronomy, 200 B.C. to A.D. 300," *ANRW* II 37.4 (forthcoming), section 5.4. *PCarlsberg* 32 was most recently published in O. Neugebauer and R. Parker, *Egyptian Astronomical Texts* 3 (Providence 1969) 240–241 and plate 79B.

as in the lunar scheme. The true position is ahead of the mean position in longitude from conjunction to Θ, and behind during the other half of the synodic cycle, so that in the template the argument of latitude would have been greater than mean from Γ to Θ, less from Θ to conjunction, and greater again to the end of the template. Pliny says that the latitude "rises" from Γ to Θ, and "descends" after Θ, which is a plausible misunderstanding where his source probably said that the latitude is "augmented" or "diminished." The only respect in which Pliny seems to have deliberately interfered with his source is in the account of the motion in "altitude." According to a geometrical model, the altitude would ascend from Γ to Θ, descend from Θ to conjunction, and ascend again from conjunction to Γ. These are, of course, the same intervals during which the "latitude" was ahead, behind, and again ahead of mean, and this explains Pliny's remarks (2.67) about the opinion of "many" that the ascent and descent in latitude correspond to the variations in altitude (*hac constare et tertiam illam a terra subeuntium in caelum, et pariter scandi eam quoque existimavere plerique falso*). Pliny's notion that the motion in altitude is caused by solar rays acting only at angles of elongation of 120° compels him to restrict the ascent and descent to the intervals immediately following the stationary points, where the planet is supposed to come under the influence of the rays.

The patterns of longitudinal motion for the inner planets are set out in less detail by Pliny. Nevertheless, it is noteworthy that he tells us that Venus attains its greatest speed at Σ, and maintains it until Ξ. This shows that he is referring to an arithmetical scheme in which the daily motion is assumed to be constant during this interval of invisibility (in a geometrical model, the speed is greatest only at conjunction). Pliny's equation of Mercury's Ω and Γ with the stationary points is a practice originating in the Babylonian arithmetical schemes, also followed in the template for Mercury, *PCarlsberg* 32. Unfortunately, Pliny has not transmitted to us authentic information concerning the latitudinal motion of Venus and Mercury, but instead simply transfers the pattern of ascent after "morning rising" and descent after "evening rising" from the outer planets, where it was applicable, to the inner planets, where it is not. The expected pattern would be *descent* from Γ to superior conjunction (not Ξ), ascent from thence to inferior conjunction, and descent for the rest of the cycle.

The alleged relative times of "ascent" and "descent" at the end of 2.76 must pertain to the motion in altitude according to Pliny's heliodynamic theory. I suggest that he derived his ratios from numbers of days specified by his source for the intervals from the stations to the immediately subsequent phases, since these are the only times during which Pliny believed that the ascent and descent took place. According to the Saturn template *PSI* 1492 the time of "ascent" from Φ to Θ is 55 days, i.e., very nearly half the 119 days of "descent" from Ψ to Ω. Analogous data from Greek templates for the other planets are not available, but we can get a rough idea of what they would have been from the Babylonian schemes from which they presumably descended.[17] A Babylonian velocity scheme for Jupiter (System A′) specifies four months from Φ to Ψ (hence two months from Φ to Θ) and four months from Ψ to Ω, exactly matching Pliny's ratio. For Mars, a ratio of six to one (rather than Pliny's four to one) would best fit the time intervals between these phases. The ratio of the time between Venus's Φ and Σ ("ascent") to the time between Ψ and Ω ("descent") varies in Babylonian tables, but fifteen to one is a quite reasonable average. For Mercury, the intervals from Ω to Γ ("descent") and from Γ to Σ ("ascent") are of roughly the same length, although these too are variable in the Babylonian schemes.

For all his obscurity, Pliny turns out to have some information to yield concerning the evolution of practical methods of astronomical computation. Evidence for Greek use of template schemes for computing the positions of the heavenly bodies has hitherto dated from the second century or later. If my interpretation of his source is correct, however, Pliny had at his disposal either a set of planetary templates or (what is more likely) a summary of their plan and contents. The fact that such a text was known to a Latin author of the mid first century narrows considerably the possible interval between the transmission of the elements of Babylonian mathematical astronomy into Greek, probably during the second century B.C., and the adaptation of these elements into the template schemes.[18] Since Pliny is not likely to have been well informed about the latest developments in astronomy, we can infer that the templates were already common knowledge by the middle of the first century. Moreover, it is only from Pliny that we learn that the planetary template schemes involved latitudinal, as well as longitudinal, motion. The Babylonian planetary schemes from which the Greek schemes derived had made no attempt to describe latitudinal motion, presumably because it was of little intrinsic interest to the Babylonian astronomers, whose chief concern was with predicting the dates and positions of the phases.[19] At the other end of the development of ancient mathematical astronomy, we have Ptolemy's elaborate (and evolving) latitudinal

[17]For details, see Neugebauer, *HAMA* 434–473.

[18]For the nature and date of the transmission of Babylonian predictive methods into Greek, see Jones, "Models and Tables . . ." (above, n. 16), section 3, and "The Adaptation of Babylonian Methods in Greek Numerical Astronomy," *Isis* 82 (1991, forthcoming).

[19]Variations in latitude have an influence on the planetary phases, but because of the nearly stationary nodal lines of the planetary orbits this effect could be built into the Babylonian schemes without requiring a separate theory of latitude. This is not the case for the moon, and indeed we find a highly sophisticated treatment of latitudinal motion in the Babylonian lunar schemes. For an anomalous cuneiform text apparently dealing with a planet's (Saturn's?) latitudes, see Neugebauer, *HAMA* 554.

theory.[20] But information concerning the Greek antecedents of Ptolemy's work on this topic has up to now been limited to scarcely more than a few limiting values for the latitudinal deviations, in particular from Pliny (2.66) and Cleomedes (*De motu* 2.7).[21] While the new evidence that we have extracted from Pliny makes it clear that some sort of scheme was developed before Ptolemy for predicting planetary latitudes for arbitrary dates, we remain ignorant of the details of how this was done. The chief difficulty is that accurate planetary latitudes cannot be calculated solely as a function of the argument of latitude (as the moon's latitudes can), because the planetary orbits do not lie in planes passing through the earth. My suspicion is that the template schemes were based on an oversimplified model like that of Fig. 2, in which the entire model lies in a single inclined plane passing through the earth, so that that latitude is simply a function of the true argument of latitude (ω) which is affected by the motion in "depth." If the assumed model involved more than one plane, there would have had to be a second component in the computation, reflecting the direct effect of the planet's varying "depth" through its synodic cycle.[22] Perhaps the discovery of further astronomical papyri may eventually settle the question.

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[20] Ptolemy's progressive models for the planetary latitudes are ably discussed in N. M. Swerdlow and O. Neugebauer, *Mathematical Astronomy in Copernicus's* De Revolutionibus (New York 1984) 486–491.

[21] Neugebauer, *HAMA* 782.

[22] There is an analogous uncertainty about whether the planetary template schemes attempted to account for the zodiacal anomaly, i.e., the variations in the synodic cycles as the planet's longitude progresses along the ecliptic; see Jones, "A Greek Saturn Table" (above, n. 16) 315–316.