Contents of This Handout

Text 1 Simpl.

Here Simplikios (6th cent. CE), In Aristotelis de cael. (Commentary on Aristotle, On the Heavens), 32.12-27) describes the failures of the homocentric system. Since his target is his despised contemporary, Joannes Philoponos, the text is clearly not a paraphrase of an earlier commentary.

source: Simpl.

I say that Aristotle in these matters says merely the following, that circular motion is about the middle; for this is appropriate to every circular motion. If he says that circularly moving bodies move about the center of the whole in other bodies, you should know that he makes his argument according to the hypotheses of the older astronomers. For the circle of Eudoxos and Kallippos and up to Aristotle supposed unwinding spheres which are homocentric with the whole and through these attempted to preserve the phenomena with regard to their saying that the spheres move about center of the whole and their not having the ability to present by those hypotheses the causes of apogees, perigees and apparent advances and retrogradations and the apparent anomalies in motions. For this reason the circle of Hipparkhos and if anyone was before him as well as Ptolemy after him supposed eccentric spheres and epicycles, and through these hypotheses rejected the view that the heavenly bodies move about the center of the whole, but by these hypotheses they present the causes of the matters we mentioned earlier, which were neglected by those. And so Aristotle says nothing about these things, but the matters on which he speaks are evident as following from the hypotheses of those earlier (astronomers).

phenomena

Text 2 Simpl.

In this attack on Alexander, Simplikios conflates the argument on the order of the planets in the Syntaxis, with that of the order and distances of the planets in the Planetary Hypotheses. More important, it suggests that Alexander is not influenced by Ptolemy on an important issue. In de Caelo, 474.7-28 (ad 291ª29).

source: Alex. with Ptolemaic critique

Alexander says that "the fact that the larger spheres by their own nature move faster, but the higher spheres move more slowly as they are impeded by the non-planetary sphere made trustworthy form the fact, as he says, that the spheres of Mars and Mercury are, as he claims, higher than the Venutian sphere and for this reason also the larger spheres move with equal speed with one another and completes its rotation with the sphere of Venus. For since they are not impeded any more in the same way by the last circumference, the lesser spheres, because of the distance, move with a speed equal to the spheres which are larger than they are. But saying that the sphere of Mercury is above that of Venus either is a scribal mistake, having "Mercury" for "the Sun", or is a claim in agreement with the opinion of the ancients according to which even Plato in the Republic constructs spheres, when he says that the star of Venus is sixth from the highest and is second in paleness after Jupiter, but that the sun is seventh and the moon is eighth, with the result that Mercury is arranged above Venus. Even observations show that Mercury is fixed below Venus, where the star of Mercury is reported passing under the star of Venus. This has also been shown from the argument about the distance of their perigees and apogees. For the greatest distance of Venus has been in some way shown to be the same as the distance of the sun, since Venus is near the sun, and the greatest distance of Mercury is in some way near the least distance of Venus, and the greatest distance of the moon is near the least distance of Mercury. For these have been shown in the Syntaxis of Ptolemy, where we switch the argument for the eccentricity of the stars for the argument from the distance form the center of the earth.

Here Simplikios suggests what the job of the early astronomer is. One suspects that he here is following Alexander fairly closely (cf. 423.29). In Aristotelis de caelo, 422.1-28 (ad288^{a}13-27).

Text 3 Simpl.

p. 422.1-2.
288^{a}13-27 "Concerning the motion of it, that it is uniform" to "for anomaly comes about due to retardation and acceleration.

source: Alex?

p. 422.3-28.
This problem is the sixth problem of those presented about heaven in this book and concerns its motion, that it is "uniform and is not anomalous (13-14)." It shows this because it is also worthy for this too to be accepted for the praise of the divine body and because he makes also use of it in the argument on the shape of heaven when he says that the circumference of heaven is a measure of the motions since it is continuous, uniform, and eternal. These belong to each of the heavenly spheres. For as they are all divine the also move with a continuous and eternal motion. But since each moves with many motions, one particular to it, another rotating with the non-planetary sphere, others rotated by the so-called unwinding spheres, if they do not have a true anomaly, at least they have an apparent one. This is the wonderful problem of astronomers: when certain hypotheses are given to them, i.e. to the ancient astronomers in the circle of Eudoxos and Kallippos, whom Aristotle also follows, the so-called unwinding spheres about which he teaches in the Metaphysics, and to those who came later certain eccentrics and epicycles, for them to show all the heavenly bodies as moving in a circular and uniform motion, although each of them moves in an apparent anomaly, sometimes faster and sometimes slower, sometimes forward and sometimes backwards, and up and down, and sometimes it happens that they are seen to stop in the same place and that the some bodies appear larger and smaller, that all these sorts of things are merely appearances and are not true. But he will show the uniformity of these when he speaks about the unwinding spheres in the Metaphysics, but for now he shows merely that the first motion is uniform, as he (Alexander) says, since, as I believe, all the demonstrations apply to the planets, and since the first motion also is apparently uniform; for this reason it is now required to show things about that sphere that there is no need for certain hypotheses.

phenomena

According to Sosigenes, Plato set the fundamental astronomical problem for astronomers. According to Eudemos of Rhodes (via Simplikios via Sosigenes), Eudoxos was the first to work on this problem--from Simplikios, In Aristotelis de cael. (Commentary on Aristotle, On the Heavens) II 12 292^{b}10 (p. 488.3-24):

Text 4 Simpl.

source: Alex. or Sosigenes

And so in this way Aristotle presented the solution to the difficulty and applies it to the difficulty. He agrees that the planets have many motions in kind due to not merely their apparent forward motion, but also their retrogradations and stations and different phases and advances (westward) and followings (eastward) and many sorts of anomaly. For since these motions are to be preserved they accept many motions for each star; some suppose eccentrics and epicylcles, and others homocentrics, the so-called unwinders. For the true account accepts neither their stations or their retrogradations, nor additions or subtractions in the number of their motions, even if they appear as moving in this way, and it does not allow that the hypotheses hold in this way either. Yet by taking evidence from their essence, it proves the heavenly motions to be simple, circular, uniform, and regular. Unable to get precisely how, given their dispositions, their attributes are merely an appearance and not true, they sought to discover by which hypotheses they would be able to preserve the appearances of the motions of the bodies that are said to wander (i.e., planets) through uniform, regular, and circular motions. And Eudoxos of Knidos was the first of the Greeks, as Eudemos relates in Book ii of The History of Astronomy, as does **Sosigenes** as well,[1] who gets this from Eudemos. He is said to have attached himself to these sorts of hypotheses of Plato (427-347 BCE), who set this problem for people who had inquired into these things, i.e., given what hypothesized uniform and regular motions the appearances of the motions of the planets would be preserved, as **Sosigenes** says.[2]

phenomena

Eudemus Fr. 148

Eudoxus, Plato, Eudemus, and Sosigenes

Note that according to The Elements of Astronomy I §§18-21 attributed to Geminos (1st cent. BCE), this story is about Pythagoreans. The problem is: who gets called a Pythagorean?

Text 5 Geminus

In these matters our study is to find out how, given that the quarters of the zodiacal circle are all equal, the sun moves at the same speed while traveling through these equal segments of the circumference in unequal times. For it is supposed in the whole of astronomy that the sun and moon and five planets move with equal speeds and circularly and oppositely to the whole universe. For the Pythagoreans were the first to proceed with these sorts of studies and supposed that the motions of the sun and moon and the five planetary stars were circular and uniform. For they would not accept such disorder for divine and eternal things: that they sometimes move faster, sometimes slower, and sometimes stop, which they also call 'standing still'. No one would accept such irregularity of motion in a finely adorned and orderly person. For the needs of life are often causes for slowness and fastness in humans. But it is not possible for any cause of fastness and slowness to come near the indestructible nature of the stars. So for this reason they posed the question in this way, how would the phenomena be provided through circular and regular motions.

phenomena

≈ Eudem. Fr. 148

phenomena

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[1] According to Proklos, Hypotyposis astron. posit., Ch. 4. 98.1-3, the work was entitled, Book on unwinders (or possibly Books on unwinding spheres): τοῖς περὶ τῶν ἀνελιττουσῶν ‹σφαιρῶν›.

[2] Note that Simplikios does not suggest that Eudemos is a source for this.

Text 6 Simpl.

Simplikios, In Physica Aristotelis, 291.3-292.31, also relates an early account of the goal of the astronomer. Here too the source is Geminos (the same one?). But Simplikios actually does not have this book. He is probably quoting from a commentary by Alexander of Aphrodisias (end 2nd cent. CE), who is quoting from the abridgment of Poseidonios' book on Meteorology (actually a general book on nature). Poseidonios was a stoic, who lived about 100 BCE, but Simplikios identifies the text as Aristotelian. We can also find echoes of Plato in the "dance" of the stars on the ecliptic.

source Alex. for Geminus for Posidonius

Alexander painstakingly transcribed a certain account of Geminos from his Epitome of the Meteorology of Poseidonios, which takes the starting points for its interpretation from Aristotle. It goes like this:

> In the theory of nature one's investigation concerns the essences of heaven and of the stars, potency and quality, coming to be and passing away, and, by Zeus, it is able to make demonstrations about size, shape, and the arrangement of these. Astronomy doesn't attempt to say anything about this sort of thing, but demonstrates the order of the heavenly bodies and truly reveals heaven as an arrangement (kosmos), and talks about shapes and sizes of the earth, sun and moon, and the distances between them, and about eclipses and conjunctions of stars and about the quality and quantity in their motions. Thus, since it touches on the observation in respect of size, manner, and quality in a figure, it is appropriate that it needs arithmetic and geometry for this. And it has the ability to prove things demonstratively about these things, while it undertakes to present an account for them alone. For it often happens that the astronomer and the naturalist propose to demonstrate the same general point, e.g., that the sun is big, that the earth is spherical, but they won't proceed on the same paths. For one of them will demonstrate each from the essence or potentiality or from this being better or from its coming to be and its changing, while the other will demonstrate from the attributes of the shapes or sizes or from the amount of motion and from the time the motion takes up. And the naturalist often touches on the cause and looks to the productive capacity, but whenever he demonstrates from external attributes the astronomer is not an adequate observer of the cause, e.g., whenever he presents the earth or the stars as spherical; and sometimes he does not even seek to get the cause, as when he discusses an eclipse. Other times, according to an hypothesis, he discovers and presents certain set-ups such that if they are the case the phenomena are preserved. E.g. why do the sun and moon and planets appear as moving anomalously? If we hypothesize their circles as eccentric or the stars as rotating on an epicycle, their apparent anomaly will be preserved. It follows that it will be necessary also to discuss all the set-ups which are possible for these phenomena to be accomplished, in order for the treatment of the subject of planets to fit the explanatory account which accords with the possible set-up. Hence too someone came along, Heracleides of Pontos, and said that if the earth somehow moves and the sun somehow remains stationary the apparent anomaly of the sun can be preserved. It is not at all the job of the astronomer to understand what is by nature at rest and what sorts are capable of motion, but by introducing hypotheses of some being at rest and others moving he examines from which hypotheses the heavenly phenomena will follow. But he must get principles from the naturalist, that the motions of the stars are simple and regular and arranged. Through these he will demonstrate that the dance of all of them is circular, some dancing in parallel and others spiraling on tilted circles.

phenomena

And so, in this way, Geminos too or rather Poseidonios via Geminos relates the distinction between the naturalist account and astronomy, getting his motivation from Aristotle.

Text 7 Simpl.

main source Alex or Sosigenes (for Eudemus) also Alex., Iamblichus (& for Nicomachus?), Nicomachus, Porphyry, Ptolemy, and others

phenomena, source is not likely Sosigenes since the text is ad loc.

In a subsequent discussion of On the Heavens II 12 293ª4 (In Arist. de cael. pp. 491.15-510), Simplikios gives our most detailed account of the theories of Eudoxos, Kallippos, and Aristotle as well as the subsequent rejection of their theories. Reader be warned. His source is not Eudemos, but Sosigenes. We cannot assume that Sosigenes is always relying on texts and not his own or someone else's rational reconstruction of history. In reading this passage we should be attentive to how Simplikios reports his sources. How much do his sources know and what are their sources?

p. 491.13-14.

293ª4-12 'And yet for this reason all the other spheres have one body' to 'the power of every limited body is related to a limited body.'

pp. 491 15-492.11

This is another dialectical argument, whether the second or third, which presents the cause of the planetary spheres each having one star but the non-planetary having many, namely as a result of what he calls the unwinding spheres. And so, he describes the sphere which holds the single star which is said to wander on many so-called unwinding spheres or, as Theophrastos calls them, starless spheres. He says that this sphere is fixed and is carried by them, being the last in their whole system, as in the case of the spheres which move Saturn or Jupiter or any of the others. And yet each sphere which holds the star, as well as those which surround it, has is own distinct, natural, simple motion. The variegated and irregular motion of the star, which seems to advance and to return and to diminish in degrees and to stop, gets added from outside it. For it arises when each of them along with its own distinct motion gets moved by the unwinding spheres, as was said, and a different sphere moves the sphere holding the star with a different motion, along with its own proper motion. Now, each sphere happens to be a body, but the outermost sphere in each system is moved along with the non-planetary stars, but with its own distinct motion. This very same motion it additionally **[492]** imparts in common to all the other spheres under it. Hence, it would be laborious for it to move both so many bodily spheres and that which has the single star, which would no longer hold one star, but many stars, as in the case of the non-planetary sphere. Aristotle reveals this laboriousness through his claim that "The power of every limited body is with respect to a limited body." For if the mover had unlimited power, it wouldn't be a matter of lots of things lying under it having to get moved, but since a limited body has limited power, this power would be related to a limited body commensurate with it and not to any body whatsoever. Hence, if it had to exceed the moving power of the one sphere in order for so many bodies to get moved by it, and if the sphere which has one star had many, the required conditions really would be difficult.

492.12-24

I think this argument preceeds that one which says that the non-planetary sphere is very much preeminent over the planetary spheres (393ᵇ29-4ª4). For, just as by its motion the non-planetary sphere moves together all the stars on it and the spheres which it surrounds, so too what would have prevented the outermost of the unwinding spheres from moving the unwinding spheres under it and the sphere holding no longer one star, but many? That is the case unless there is a difference in the following: on the one hand, the non-planetary sphere, which exists with its stars and moves with its own motion, thereby turns around together the spheres which it surrounds, and, on the other, the sphere having the planetary star (if instead it held a multitude of stars) makes the motion of it produced by another more laborious for the mover. The hard labor is not due to those bodies having heaviness. For Aristotle refuted this with a demonstration (de Caelo I 3); rather it is due to the fact that it is also altogether necessary that there be in those things a symmetry of the mover with regard to the moved. Because of this, Aristotle has made the demonstration from this principle.

492.25-494.22

Text 7a digression source Sosigenes

We have to understand that this dialectical argument also proceeds against the view that the true astronomical hypotheses of unwinding spheres have no necessity, as I also stated earlier, if in fact others also preserve the phenomena through other hypotheses. A brief discussion concerning these hypotheses, by the supposition of which everyone sought to preserve the phenomena, might be appropriate to these accounts of heaven and the heavenly motions. I also said earlier that having without hesitation assigned to the heavenly motions the properties of being circular, uniform and regular, Plato **[493]** posed a problem to the mathematicians: **{**supposing what things will it be possible through circular, uniform, regular motions to preserve the phenomena with regard to the planets, and that Eudoxos of Knidos was the first to attend to it by means of hypotheses through the so called unwinding spheres.[3] Kallippos of Kyzikos, a schoolmate of Polemarkhos, who was a pupil of Eudoxos, came to Athens after him and lived with Aristotle. Together with Aristotle, he corrected and filled out the discoveries of Eudoxos.**}** For Aristotle, who thought that all heavenly bodies ought to move around the middle of the whole, liked the hypothesis of unwinding spheres inasmuch as he supposed the unwinding spheres as homocentric with the whole and not eccentric, as astronomers later supposed. **{**Now, Eudoxos and his predecessors thought that the sun moved in three motions: it rotates together with the non-planetary sphere from risings to settings (east to west), it moves in the opposite motion through the twelve zodiacal signs, and, thirdly, it deviates sideways near the circle running through the middles of the zodiacal signs.[4] For this assumption was based on the claim that the sun does not always set in the same place in the winter and summer tropics. So, for this reason, they used to say that the sun moves in three spheres, which Theophrastos used to call 'starless' since they have no star and rotate backwards with respect to those below and unwind with respect to those above. For given its three motions, it is impossible that it be moved in opposite motions by the same thing, if, at least, neither the sun nor the moon nor any other star moves in virtue of itself, but all move by being fixed to the circular body. In fact, if it made its lengthwise path (i.e. longitudinal path) and its widthwise side-motion (i.e. latitudinal motion sideways) in one and the same time,[5] the two spheres would have been independent, with one revolving with the non-planetary stars to the settings (west), and the other rotating towards the dawn (east) about an axis fixed to the first sphere and at right angles to the ecliptic, on which the sun would be thought to make its path. Since this is not the case, but it revolves on the circle in one time and makes its latitudinal sideways motion in some other time, it is necessary to add on a third sphere, so that each [real] motion presents each of the apparent motions of the sun. In this way, given three spheres, **[494]** all homocentric with one another and the whole, it is supposed that: one rotates about the poles of the universe completing its revolution in the same spots and in equal time as the sphere of the non-planetary stars; the next, which is smaller than this, but greater than the last, rotates about its axis as stated, at right angles to the plane of the zodiacal circle from settings to risings (west to east); and the smallest turns round to the same spots as the second, but about a different axis, which is conceived as being at right angles to a plane of a certain oblique great circle, which the sun seems to draw with its own center under the smallest sphere, on which it is also fixed. And so he posits the deficient motion [eastwards or slower westward motion?][6] of this sphere as much slower than the motion of the surrounding sphere which is middle in magnitude and position. This is clear

{using Eudemus

Start Eudemus Sun

3rd sphere pheno-mena Theoph. all spheres unwind

perhaps not Eudemus

direction sphere 3?

3rd sphere motion

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3 E.g., cf. p. 488.13-24.

4 This expression which occurs, inter alia, in Met. Λ 8, I suspect, implies a conception of the zodiac as like a frieze, perhaps as on a tholos temple. The middle of each zodiacal sign (διὰ μέσων τῶν ζωδίων), i.e., each tableau on the frieze will then be a point midway between the top and bottom of the frieze. The circle going through the midpoints will be the ecliptic circle. For convenience, I shall conventionally translate this phrase subsequently as 'zodiacal circle'.

5 One question which this text raises is when the word 'width' (πλάτος) came to mean 'latitude' and 'length' (μῆκος) came to mean 'longitude'. If this text is by Eudemos (as I suspect), then it could be very early if πλάτος here means latitude, but we cannot rule out the possibility here that the language is all Sosigenes. In any case, it would require

from the treatise written by him On Fast Things. The greatest of the spheres, accordingly, turns the remaining two towards the same spots as the non-planetary stars since it carries the poles of one of them on itself, while that sphere carries the poles of the third which carries the sun. For it similarly has the poles of the third sphere on it and rotates, together with itself, the third sphere, and with it the sun, towards the spots it is turning to. In this way the sun happens to appear as moving from risings to settings (east to west). If in fact the middle and smallest spheres were unmoved in virtue of themselves, the rotation of the sun would take place in a time equal to the rotation of the universe. But since these turn oppositely, the return from rising (east) to the subsequent rising (east) is later than the time I just mentioned.[7]

treatise title

494.23-495.16

Text 7b

Moon

And these dealt with the sun, but with regard to the moon, he arranged some things in the same way, and others differently. For he says that there are three spheres which move it. From this, there also appear to be three movements of it, where one of these is the one which is similarly produced by the sphere of the non-planetary stars, and another moves oppositely to this, but turns about an axis which is at right angles to the plane of the zodiacal circle, just as in the case of the sun, but the third is no longer like the sun's. For, its position is similar, **[495]** but its motion is not. Instead it moves oppositely to the second and moves towards the same spots as the first sphere, turning in a slow motion but about an axis at right angles to the plane of the circle which is conceived as drawn by the center of the moon and inclined to the zodiacal circle by as much as occurs in the greatest sidewise movement in latitude. It is evident that the poles of the third sphere are separated from those of the second sphere by the circumference on a great circle conceived as going through the two. Its size is half the latitudinal movement of the moon. And so he supposed the first sphere because of its orbit from risings to settings (east to west), the second because of its advance motion which appears under the zodiac, and the third due to the fact that when it is most northerly and most southerly it does not always appear on the same points. of the zodiac, but instead such points of the zodiac always move towards the leading signs [east to west]. Hence too he supposed this sphere moves towards the same spots as the non-planetary stars, but because the change of the mentioned points is extremely small in each month, the motion towards the settings (westward) is slow.[8]

3rd sphere with direction

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an argument to show that πλάτος does not mean latitude with respect to some rotating sphere's equator or even the spherical width between two arcs in Met. Λ 8.1073^{b}21. In fact, I suspect that this is all that it need mean in the "Eudemos" text and in Aristotle's text. Subsequently, I shall translate these terms conventionally as 'latitude' and 'longitude', but with these questions remaining in the background.

6 This is a problematic text (τὴν οὖν ὑπόλειψιν τῆς σφαίρας ταύτης βραδυτέραν πολλῷ τίθεται ἢ τὴν τῆς περιεχούσης αὐτήν). If the text is in Sosigenes' words, then it certainly means 'eastward motion' (besides this being normal astronomical usage, cf. 501.28), motion of stars left behind by the westward movers, in which case the third sphere moves eastward. If we look to 4th cent. BCE texts, the issue is not so clear. If the meaning is 'deficient motion', then the motion may be a slower motion in the same direction or a motion in an opposite direction. In Epicurus, Letter to Pythocles 114, it may just mean that the motion is slower than the eastward motion of some other star, so that it could still be a westward motion. In Meteor. A 6.343^{a}4, 6,17, 24, 29, the deficient motions would appear to be merely motions slower than the ecliptic motion of the sun. If so, then a reasonable model for the sun might have the second sphere rotating at a rate of t(1/365 1/4 - 1/X) days and the third sphere in t/X days in the same direction. Moreover, just above the text says that the third sphere moves to the same spots as the second (τὴν δὲ ἐλαχίστην καὶ αὐτὴν μὲν ἐπιστρέφεσθαι ἐπὶ ταὐτὰ τῇ δευτέρα). Hence, this possibility is not easily ruled out. It will violate Sosigenes' principle that the spheres all unwind in some way.

7 This model may be reconstructed as follows: let m_{δ} be the average time it takes for the sun to return to the true ecliptic, m_{λ} be the average motion of the ecliptic circle, and m_{s} be the average motion of the fixed stars. The motion of the first sphere will be m_{s} (east/west), the motion of the second sphere will be $m_{\delta} + m_{\lambda}$ (west/east), and that of the third sphere will be m_{δ} (east/west). Cf. H. Mendell, "Reflections on Eudoxus, Callippus and their curves: Hippopedes and Callippopedes", Centaurus, Aug. 1998.

8 Understanding this last sentence is crucial for getting a correct interpretation of the lunar theory and of the whole passage. Until now, all commentators have read this as suggesting that the motion of the third sphere is very slow. However, the text merely says that the motion of the points of most northerly and southerly positions is slow, i.e. the net nodal motion. Hence, the model can be the same as that for the sun. Cf. Mendell, op. cit.

Text 7c

495.17-497.5

Planets

So much for the moon, but in setting out his opinion concerning the five planets, Aristotle says that these move through four spheres, of which the first and the second are the same and have the same position as the first two spheres which occur in the case of the sun and moon. For, in each case, the sphere which encompasses all of them is turning about the axis of the universe from risings to settings (east to west) in equal time with the non-planetary stars, and the second has its poles on the first sphere at the axis and poles of the zodiacal circle, making its contrary rotation from settings to risings (west to east), in the time in which each of them is thought to traverse the zodiacal circle. Hence in the case of Mercury and Venus, he says that the motion of the second sphere is completed in a year, but in the case of Mars two years, in the case of Jupiter 12 years, and in the case of Saturn (which the ancients used to call the star of the sun) 30. The remaining two work somewhat in the following way: the third in each case has its poles on the zodiacal circle **[496]** which is conceived as being in the respective second sphere and rotates from south to the Bears [south to north][9] in the time in which each arrives from one phase to the next phase,[10] traversing all relations to the sun in the time which mathematicians also call the time of passage [synodic year]. This is different in each case, so that not all of them have the rotation of the third sphere in an equal time. But, just as Eudoxos believed, for Venus it is in 19 months, for Mercury in 110 days, for Mars in 8 months and 20 days,[11] for Jupiter and for Saturn, being nearest to each other, in 13 months. The third sphere moves in this way and in so much time. The fourth sphere, which also carries the star, turns its poles about a certain inclined circle in each case; however, it produces its rotation in an equal time to the third but moving oppositely to the third, from risings to settings (east to west). This inclined circle is said by him to be inclined to the greatest of the parallel circles in the third sphere, but they are not equal nor the same in every case. And so it is evident that the first sphere by turning all the others in a motion similar to that of the sphere of the non-planetary stars in as much as they have poles within one another, turns towards the same spots, so that it turns both the sphere carrying the star and the star itself. And it is for this reason that it is a feature of each of them to rise and set. But the second sphere will provide it with the path under the 12 zodiacal signs. For it turns about the poles of the zodiacal circle and rotates together the remaining two spheres and the star towards the rear of the signs [i.e., in advance] in the time each seems to complete the zodiacal circle. The third sphere has poles on the zodiacal circle in the second sphere and rotates from south to the Bears [south to north] and from the Bears to the south (north to south). It will also rotate the fourth sphere which has the planet on it as well and indeed will provide the cause of the latitudinal motion. And, in fact, not merely this. For as much as it would have moved on this sphere, the star would have come to the poles of the zodiacal circle and would come to be near the poles of the universe.[12] But now the fourth sphere by turning about the poles of the inclined circle of the star in an opposite direction to the third, from risings to settings (east to west), and making the rotation of the poles **[497]** in an equal time [to the third], will excuse [the star] from traveling way beyond the zodiacal circle and provides the star with the means to trace out the hippopede, as Eudoxos called it, about this very circle, so that as large as is the breadth of this line, so large too does the star seem to move sideways in breadth [in latitude], the very thing for which they blamed Eudoxos.**}**

sphere 1

sphere 2

periods

spheres 3 and 4

direction$_3$

period$_3$

periods$_3$

period$_4$

direction$_4$

sphere$_1$

sphere$_2$

sphere$_3$

sphere$_4$

pheno-menon

END Eudemus

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9 μεσημβρία and ἄρκτος are standard terms for celestial south and north in Aristotle, cf. De caelo 297^{b}33-4, 298^{a}2-3, Meteor. 361^{a}4-7.

10 Aristotle refers to phases at Meteor. A 6 342^{b}34.

11 This should probably be emended to either '28 months' (840 days) (Mendell, op, cit.) or '28 months and 20 days' (860 days) (F. Lasserre, Die Fragmente des Eudoxus), which is nearer to an expected figure of 780 days ± 100 days.

12 It has recently been suggested by Ido Yavets, AHES, that Simplicius does not require the planet to be on the equator of the fourth sphere. Yet, it is a presupposition of this claim that whatever sphere the planet would be on, it would have to be on the equator. Otherwise, his claim that the planet would move to the pole of the second sphere would be false.

497.6-499.16 **Text 7d**

This production of spheres according to Eudoxos takes up in toto 26 spheres for the seven planets, namely 6 for the sun and moon, and 20 for the five. On Kallippos Aristotle has written these things in Metaphysics Λ:

> Kallippos posited the positions of the spheres as the same as Eudoxos, that is in the arrangement of distances, and he provided the same number for Jupiter and Saturn, but believed he had to add two more spheres for the sun and the moon, if he were to present the appearances, and an additional one for each of the remaining planets [i.e. Mars, Mercury, Venus].

Hence, according to Kallippos, all the spheres are five-times 5 and twice 4, i.e., 33 spheres. There isn't any treatise of Kallippos extant which tells the reason why these spheres must be added, nor does Aristotle add the reason, but Eudemos briefly **{**related what were the phenomena on account of which he thought these spheres had to be added. For he says that Kallippos says that if the times between the solstices and the equinoxes differ by as much as Euktemon and Meton thought,[13] the three spheres would not be adequate for each to preserve the phenomena clearly due to the manifest anomaly of their motions. The reason for the single sphere which he adds in the case of each of the three planets, Mars, Venus, and Mercury, Eudemos related briefly and clearly.**}**[14] Now Aristotle, after relating the opinion of Kallippos on the unwinding spheres, proposed:

{Eudemus Testimonium.}

Eudemus END

> If all the spheres taken together are to present the appearances, at each pole of the planets there must be other spheres, one less in number, which unwind them and which always restore the first sphere of the star below to the original position. For only in this way will it be possible **[498]** for all of them to produce the motion of the planets.

Now since Aristotle has said these things briefly and clearly in these words, **Sosigenes** praised his quickness of mind and attempted to find the need for the additional spheres proposed by him. He says that these spheres which he calls unwinders need to be added to the hypotheses for two reasons, in order for the non-planetary sphere for each planet and the spheres under it to have a proper position, and in order for there to occur a proper speed in all spheres. For it would be required that the sphere similar to the non-planetary sphere or some other sphere move about the same axis as that sphere and rotate in an equal time, none of which is possible without the addition of the spheres mentioned by Aristotle. Let's make the argument, he says, for the sake of clarity, for the case of the spheres carrying the star of Jupiter. Thus if in the last of the four spheres of Saturn, on which it is fixed, we should fit in the poles of the first of the spheres of Jupiter, how will these poles be able to remain on the axis of the sphere of the fixed stars, inasmuch as the sphere carrying them turns about a different axis at a slant to them? In fact, they have to remain on the axis we mentioned in the case of the outermost motion, if the sphere rotating about them is to receive the arrangement of the sphere of the non-planetary stars.[15] Moreover, since three of the spheres which carry the star of Saturn are rotated by one another and by the first sphere, although these have a proper speed of their own, the motion about the fourth would not be some simple motion, but would have a share of all the motions above it. For it will be shown that in the case where the spheres move against one another something is taken away from the speed which is due to their moving together, and in the case where the spheres move together something is added to the motion which penetrates to them from the higher sphere because of their own motion. Thus, if in fact the first of the spheres

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13 It may be significant that Simplikios states that Eudemos used the solar anomaly of Euktemon and Meton, as opposed to the solar anomaly of Kallippos, reported in the so-called Ars Eudoxi. Does this mean that the solar theory was concocted later than Eudemos or that Eudemos is merely talking about the idea of solar anomaly and is not concerned about a particular version? In any case, Simplikios seems unaware of a more advanced theory. For scepticism about the empirical basis of Euktemon and Meton, cf. the subtle argument of A. Bowen and B. Goldstein, "Meton of Athens and Astronomy in the Late Fifth Century B.C.", in Erle Leichty, Maria de J. Ellis and Pamela

of Jupiter is fixed to the sphere which carries Saturn and has its own proper speed, so as to return over again to the same spot as in the rotation of the universe, the motions of the higher spheres will not allow it to have this speed, but there will be a certain addition. For even these move towards settings (westward) when that same sphere also moves to the same spots. The same argument also occurs for the following planets. For the motion will be more and more composed while the poles deviate in their proper spot. But, just as we said, neither of these ought to occur. And so, in order for this not to occur and for nothing outrageous **[499]** to present itself on account of this, he contrived (Met. Λ 1074ª2) "the unwinders as also always restoring the first sphere of the next star arranged below it to the same spot in position." For in fact he said it by these very words when he disclosed both reasons for his introducing them, through his calling them unwinding with respect to the restoration of motion into the proper speed and through his saying "always restoring the first sphere of the next star arranged below it to the same spot in position" with respect to the sole restoration of the poles in the appropriate way. For by these poles, if indeed they alone remain fixed, the position of the moving spheres is ascertained. He said that the first sphere of the next star arranged below is restored by them, since, by this getting its proper position and proper speed from the rolling up, all the properties of the successive spheres are preserved.

497.6-499.16 **Text 7e**

This production of spheres according to Eudoxos takes up in toto 26 spheres for the seven planets, namely 6 for the sun and moon, and 20 for the five. On Kallippos Aristotle has written these things in Metaphysics Λ:

> Kallippos posited the positions of the spheres as the same as Eudoxos, that is in the arrangement of distances, and he provided the same number for Jupiter and Saturn, but believed he had to add two more spheres for the sun and the moon, if he were to present the appearances, and an additional one for each of the remaining planets [i.e. Mars, Mercury, Venus].

Hence, according to Kallippos, all the spheres are five-times 5 and twice 4, i.e., 33 spheres. There isn't any treatise of Kallippos extant which tells the reason why these spheres must be added, nor does Aristotle add the reason, but Eudemos briefly related what were the phenomena on account of which he thought these spheres had to be added. For he says that Kallippos says that if the times between the solstices and the equinoxes differ by as much as Euktemon and Meton thought,[16] the three spheres would not be adequate for each to preserve the phenomena clearly due to the manifest anomaly of their motions. The reason for the single sphere which he adds in the case of each of the three planets, Mars, Venus, and Mercury, Eudemos related briefly and clearly.[17] Now Aristotle, after relating the opinion of Kallippos on the unwinding spheres, proposed:

Gerardi (eds.), A Scientific Humanist: Studies in Memory of Abraham Sachs (Philadelphia: Occasional Publications of the Samuel Noah Kramer Fund, 9, 1988), 40-81.

14 This seems to be evidence that Simplikios' source neither mentions the reason nor explains the models of Kallippos. The alleged brevity also suggests that the reason was not adequately clear to the reader (Sosigenes?). Note that the case of the moon is not mentioned.

15 The word τάξις may be unclear in the text of Aristotle. Yet it is clear that here the arrangement is the position of the poles of the sphere's motion.

16 It may be significant that Simplikios states that Eudemos used the solar anomaly of Euktemon and Meton, as opposed to the solar anomaly of Kallippos, reported in the so-called Ars Eudoxi. Does this mean that the solar theory was concocted later than Eudemos or that Eudemos is merely talking about the idea of solar anomaly and is not concerned about a particular version? In any case, Simplikios seems unaware of a more advanced theory. For scepticism about the empirical basis of Euktemon and Meton, cf. the subtle argument of A. Bowen and B. Goldstein, "Meton of Athens and Astronomy in the Late Fifth Century B.C.", in Erle Leichty, Maria de J. Ellis and Pamela Gerardi (eds.), A Scientific Humanist: Studies in Memory of Abraham Sachs (Philadelphia: Occasional Publications of the Samuel Noah Kramer Fund, 9, 1988), 40-81.

17 This seems to be evidence that Simplikios' source neither mentions the reason nor explains the models of Kallippos. The alleged brevity also suggests that the reason was not adequately clear to the reader (Sosigenes?). Note that the case of the moon is not mentioned.

If all the spheres taken together are to present the appearances, at each pole of the planets there must be other spheres, one less in number, which unwind them and which always restore the first sphere of the star below to the original position. For only in this way will it be possible **[498]** for all of them to produce the motion of the planets.

Sosigenes How unwinders work

Now since Aristotle has said these things briefly and clearly in these words, **Sosigenes** praised his quickness of mind and attempted to find the need for the additional spheres proposed by him. He says that these spheres which he calls unwinders need to be added to the hypotheses for two reasons, in order for the non-planetary sphere for each planet and the spheres under it to have a proper position, and in order for there to occur a proper speed in all spheres. For it would be required that the sphere similar to the non-planetary sphere or some other sphere move about the same axis as that sphere and rotate in an equal time, none of which is possible without the addition of the spheres mentioned by Aristotle. Let's make the argument, he says, for the sake of clarity, for the case of the spheres carrying the star of Jupiter. Thus if in the last of the four spheres of Saturn, on which it is fixed, we should fit in the poles of the first of the spheres of Jupiter, how will these poles be able to remain on the axis of the sphere of the fixed stars, inasmuch as the sphere carrying them turns about a different axis at a slant to them? In fact, they have to remain on the axis we mentioned in the case of the outermost motion, if the sphere rotating about them is to receive the arrangement of the sphere of the non-planetary stars.[18] Moreover, since three of the spheres which carry the star of Saturn are rotated by one another and by the first sphere, although these have a proper speed of their own, the motion about the fourth would not be some simple motion, but would have a share of all the motions above it. For it will be shown that in the case where the spheres move against one another something is taken away from the speed which is due to their moving together, and in the case where the spheres move together something is added to the motion which penetrates to them from the higher sphere because of their own motion. Thus, if in fact the first of the spheres of Jupiter is fixed to the sphere which carries Saturn and has its own proper speed, so as to return over again to the same spot as in the rotation of the universe, the motions of the higher spheres will not allow it to have this speed, but there will be a certain addition. For even these move towards settings (westward) when that same sphere also moves to the same spots. The same argument also occurs for the following planets. For the motion will be more and more composed while the poles deviate in their proper spot. But, just as we said, neither of these ought to occur. And so, in order for this not to occur and for nothing outrageous **[499]** to present itself on account of this, he contrived (Met. Λ 1074ª2) "the unwinders as also always restoring the first sphere of the next star arranged below it to the same spot in position." For in fact he said it by these very words when he disclosed both reasons for his introducing them, through his calling them unwinding with respect to the restoration of motion into the proper speed and through his saying "always restoring the first sphere of the next star arranged below it to the same spot in position" with respect to the sole restoration of the poles in the appropriate way. For by these poles, if indeed they alone remain fixed, the position of the moving spheres is ascertained. He said that the first sphere of the next star arranged below is restored by them, since, by this getting its proper position and proper speed from the rolling up, all the properties of the successive spheres are preserved.

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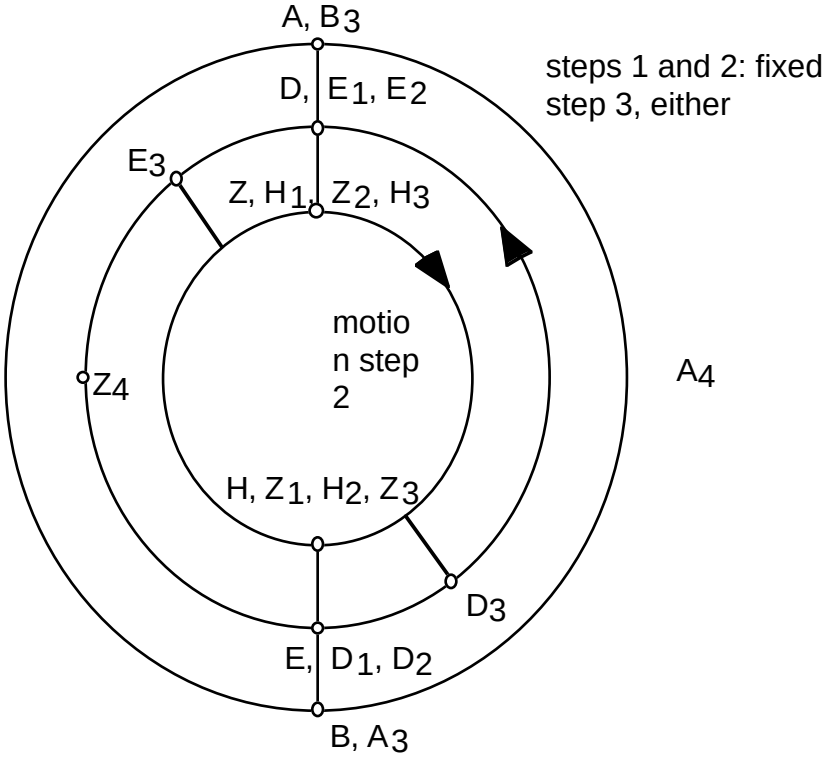
[18] The word τάξις may be unclear in the text of Aristotle. Yet it is clear that here the arrangement is the position of the poles of the sphere's motion.

499.16-500.14

Text 7f How unwinders work continued with geometrical argument, also in ps.-Alex.

Sosigenes shows that these things occur by proposing some useful things for the argument, for which the following is an abridged display [of the diagram] (see Simplikios, Diagram 1).[19] Let there be two homocentric spheres, e.g., DE, ZH, and let them be enclosed from the outside by another sphere which either is fixed or turns them around, where those two move oppositely to one another and in an equal time, i.e., with equal speed. All the points in the encompassed sphere will always be in the same spot with respect to the encompassing sphere, as if it too happened to be fixed. For when DE moves, e.g., from A to B, if the lesser ZH merely turned around with it and did not carry it backwards, it would be seen that as D at some time moves under B so too Z moves together with D and in equal time. Since they both move together, and ZH moves opposite to DE, as much as it adds to the motion by moving with it, so much does it undo the motion by moving against it. And it happens that when D is under B, Z is under A, just as it appeared from the start. **[500]** Thus the proposed claim is true. Hence it is clear that when AB is fixed what was shown is clear, also with the result that[20] when both occur, it is also clear that the inner moves together with and opposite to the outer sphere and so has the same position always with the same points and neither merely moves with it nor merely moves opposite to it. If in fact AB also moved, whether oppositely or in the same direction as the second sphere DE, the same things will follow with respect to the points of the third sphere moving similarly together with and oppositely to DE. For if when sphere AB is turned from A to B and drags with it sphere DE, where D comes to E, the middle sphere itself DE will move oppositely or in the same direction as AB with whatever speed in relation to AB, but in the direction of sphere ZH and at the same speed. And since the third sphere turns with it, it makes point Z pass by A. But the third sphere again moves against it and makes Z be under A. While this keeps occurring, all the points on sphere ZH will be under the same points on sphere AB.

Figure 1 for Simplikios, In De caelo 499.16-500.14



19 The following demonstration appears in a confused version in ps.-Alexander, In Arist. Met. Λ 8, 704.21-706.6.

20 Is there a lacuna after ὅπως? Heiberg sees a corruption here, but does not propose a solution.

500.15-500.21[21] **Text 7g**

And so we have now shown what was proposed for spheres moving about the same axis, but the argument is the same even if they don't move about the same axis. For it is not due to the motion of the same parallels that the position of the points occurs under the same points, but due to the fact that the joint rotation of the enclosed sphere with respect to the enclosing and contrarily rotating sphere takes away as much as this adds to the motion, whether the rotation which results and the contrary rotation is on an inclined circle or at right angles.

500.22-501.11 **Text 7h**

Again, given two homocentric spheres moving in the same direction each at some speed and the smaller not merely moving with the larger, but also having its own motion in the same direction, if the speeds are equal, the composed motion will appear as double the speed, but if the speed of one is double, the speed of the composed and successive motion will be threefold, etc. For if the greater moves the lesser a fourth, and this moves with equal speed a fourth, then it will have moved two fourths, so that the motion composed from **[501]** both is double either motion. We say these things, he says, if the motions are about the same poles. But if they are not about the same poles, something else will occur due to the inclination of the other sphere. For the speeds will not be composed in this way, but rather in the way that one is used to showing on a parallelogram, where the motion on the diameter is the result of two motions: one motion of a point moving on the length of the parallelogram and the other a motion of this length moving down in an equal time through the width of the parallelogram. For both the point on one end of the diameter and the side of the length, which is led down, will be together, and the diameter will not be equal to both lines reflected at the same point, but will be less, so that also the speed will be less than that composed from both, but nevertheless it is composed from both.

For David Fowler Composition of motions (reasonable)

501.12-501.21 **Text 7i**

And that is nearly what is said by these words: given two homocentric spheres, whether they rotate about the same poles or different ones, but rotate oppositely to one another and with the smaller sphere rotating less against the other, but being rotated by the larger, the points on the lesser sphere will have come to the same spot in more time than they would have if the smaller sphere happened to be merely fastened onto the larger. For this reason even the return of the sun itself from rising to rising is slower than the rotation of the universe, for the reason that it moves opposite to the whole more slowly.[22] For if, in fact, it moved equally with the non-planetary sphere but were rotating oppositely and always returning in the same time, it would always rise together with the same point.

501.22-503.9 **Text 7j**

After these have been assumed, **Sosigenes** proceeds to Aristotle's claims concerning the need for "there to be other unwinding spheres in the case of each of the stars, and for their number to be one less [than the spheres in the Eudoxan and Kallippan models], if the phenomena are to be presented (Met Λ 8.1074^{b}36-5^{a}3). Setting out his theory of Aristotle's sphere production, he says:

Motivation for unwinders

> If in the case of the spheres carrying Saturn the first sphere moves according the motion of the non-planetary stars, the second falls behind (ὑπολειπομένη, cf. note 6) along the zodiacal circle, and the third is at right angles to the zodiacal circle, which carries it in latitude from the south to the Bears (south to north). This circle is at right angles to the zodiacal circle, whence it has its poles on it--circles which cut through the poles cut at right angles. The fourth sphere, which holds the star on an oblique circle **[502]** moves it, with this circle putting a limit on the latitude of

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21 This part of the argument looks like an attempt at mathematical induction.

22 Cf. 494.20-22.

deviation towards the Bear (north) The result is that it does not come to be near the poles of the universe.[23] We ought, therefore, to conceive of another, fifth sphere before those carrying the planet, which moves via four spheres [i.e., of the planetary system above it], around the same poles as the fourth, turning oppositely to it and in equal time. For this will take away the motion of the fourth sphere because it moves about the same poles as it, although oppositley and in equal time. For this was shown. And it diminishes the apparent speed. But after the fifth, we need to conceive of a sixth sphere which has its poles be the same as the third's and unwinding it by moving both in equal time and oppositely, so that the phenomena may be preserved and that the points on the third sphere always appear at the same perpendicular on the fifth. After this, we need to add a seventh which unwinds the second with its poles fitted onto the zodiacal circle, about which that also moves, however rotating oppositely to and in equal in time with the second, and taking away the motion and speed which is passed on from it to the spheres below it. For the second sphere too moves together with the non-planetary sphere and adds to the speed from risings to settings (east to west) of those under it. And so it turns in this way, moving similarly to the non-planetary sphere. However, it will not have the arrangement of the non-planetary sphere as well, although it turns [other] poles, not the poles of the non-planetary sphere, from risings to settings (east to west).[24]

After this we must lastly conceive of an eighth sphere which is the first sphere of Jupiter, as **Sosigenes** rightly establishes,[25] since the last of the three unwinders is not the first of the spheres of Jupiter, which is what some thought, namely that the last of the spheres unwinding the motions above it will be the first of those carrying the next star below, so that the same sphere is both seventh and what we call the eighth sphere although it is the first of the spheres of Jupiter. For it turns out that they count the same sphere twice in their attempt to preserve the number of unwinders stated by Aristotle. For in the case of each star, the unwinders need to be one less than the number of carrying spheres, so that in the cases of Saturn and Jupiter, where there are four carrying spheres, the unwinders must be three in number, but[26] in the case of the remaining four, Mars, Venus, Mercury, sun, where the carriers are five, **[503]** the unwinders are four. And so the total number of unwinders will be twice three for Saturn and Jupiter, and four times-four for Mars, Venus, Mercury and the sun, so that the total is 22. The carriers are eight for Saturn and Jupiter, but 25 for the remaining five. And so, since these are 33 added to 22 unwinders, the total is 55. For there is no need for unwinders to be added to the carriers of the moon, since this is last, given that Aristotle also says this (Met Λ 8.1075^{a}7-8), "there is no need for the spheres on which the low[27] star in order moves alone to be unwound."

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23 Cf. 496.23-497.5.

24 The sense of this passage is that the first sphere transmits to the second an east/west motion which it tranmits to the spheres below it. Since the motion of the second sphere is less than that of the first sphere (one rotation in a least a month, as opposed to one a day), the net motion is east to west.

25 Since the seventh sphere unwinds the zodiacal motion (west/east), what is left will be the daily motion of the first sphere. In other words, by Sosigenes' count, the seventh sphere will have a net rotation of the outermost sphere. Hence, the seventh sphere will be the first sphere of the next planet. Thus, the total number of needed spheres will be 1 (fixed stars), 3 + 3 for each of Saturn and Jupiter, 4 + 4 for each of Mars, Venus, Mercury, and the sun, and 4 for the moon, or 49 spheres. If we unwind this motion, we will get the same number of unwinders as winders. In other words, the number of spheres will be 1+1 (fixed stars), 4+4 (Saturn and Jupiter), 5+5 (others besides the moon) + 5 (moon) or 63. To get Aristotle's numbers, we need to make a mistake, forgetting either that we do not need a diurnal motion for each system or that if we do we need to unwind it too. This will yield 4+3 (Saturn and Jupiter, including the sphere of the fixed stars), 5+4 (others besides the moon) + 5 (moon), for 55 spheres. Note that Sosigenes and Simplicius are fairly circumspect in pointing out the difficulty.

26 From here to the end of the paragraph the text is almost identical with ps.-Alex., In Met. 705.39-706.15.

27 Ps.-Alexandere and Simplicius have κάτω for κατωτάτω.

503.10-504.3

Text 7k Number of Aristotle's spheres

But it is clear that this is the number of all of them. Since Aristotle proposed that if[28] someone does not add[29] a sphere to the sun and to the moon the motions we've mentioned the total will then be 47 (Met Λ 8.1075ª12-14), this caused some consternation. For if we take away two spheres of the sun and two of the moon, which Kallippos added, and clearly two other unwinders as well from the sun (for when those are taken away we need to take away with them also the spheres which are to unwind them), there will be six spheres taken away, two carrying the sun, two unwinding these, in addition to two for the moon, which were added on by Kallippos. But it is not at all the case that when these are taken away from 55 the remaining spheres are 47, but rather they are 49. Aristotle says that 47 spheres remain as though he has forgotten that he took away from the moon not four but merely two, unless one should say that he took away the 4 spheres from the sun which he had added as unwinders, and from both the spheres which Kallippos [added], and so when eight are thus taken away from 55, the remainder is 47. The number does come about in this way, but why some people don't unwind two of the sun's spheres, the second and the third, we cannot say, even when he says these things, namely that the low star in position (Met Λ 8.1075ª7-8) alone is not unwound. And yet **Sosigenes** attended to this matter well since he said that there is no need in the case of the moon to suppose unwinders, so that the speed from the higher motions which is added to the spheres carrying it no longer makes it proceed towards the settings (westward) equal in speed to the non-planetary sphere. Yet where this is supposed, that it alone does not have an unwinding sphere, the number does not follow, and this bothered Alexander as well as Porphyry in his scholia on Met. Λ. Attending to the matter, **Sosigenes** says that it is better to believe that there arose an oversight in the number of the paths **[504]** than to make the seventh and eighth spheres the same, without the number where this occurs being in accord with the text.[30] For the total number of spheres will not come to 55, as he states.

End Sosigenes Alex. Porphyry Back to Sosigenes

504.4-16

Text 7l **Source still Sosigenes** Theoph.

Sosigenes additionally says this, that it is clear from what was said that in one respect Aristotle calls them unwinders, and in another Theophrastos calls them the back bringers. For both names refer to the same spheres. For they unwind the higher motions and bring the poles of the spheres under them back, some by taking away, others by bringing them into the required state. For whereas the motions from above must not be transmitted to the different motions of the stars below, the poles of the lower stars under the same perpendicular must fall on the poles of the similar spheres, so that the first spheres of the stars arranged below would be restored to the same position, just as he says, and clearly, because of the first spheres being restored to the same position, those after them will also be restored. Only in this way, he says, is it possible for all the stars to produce the motion of the non-planetary stars, as we have already stated, and he says it well.

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28 From here to 503.25 (so when eight are thus taken away from 55, the remainder is 47), and then the beginning of the quotation of Sosigenes,503.35-504.1 (Attending to the matter, Sosigenes says that it is better to believe that there arose an oversight in the number of the paths) is nearly identical to ps.-Alex., In Met. 705.30-39

29 Simplicius trivially switches Aristotle's words order a little. Ps.-Alex. doesn't.

30 This is the first intrusion into the account of authors later than Sosigenes. Simplicius is not merely quoting Sosigenes. Much is paraphrase, but he also interjects his own observations, here to the detriment of Alexander (whom he often wants to best) and Porphyry. There is no suggestion in these remarks that either is his source for Sosigenes. But it does indicate that he has (indirectly?) used both lost commentaries.

504.16-506.8: **Text 7m**

The sphere production through counter-rollers is this sort of thing, although they are not able to preserve the appearances, as also **Sosigenes** charges when he says:[31] Early (?) objections to homocentric spheres

> The spheres of the Eudoxans do not in fact preserve the appearances, not merely appearances grasped later, but also not even ones known earlier and believed in by those same people. And what should we say about other appearances, some of which even Kallippos of Kyzikos tried to preserve when Eudoxos couldn't, if in fact he did preserve them? But the following matter, which is also altogether evident to the eyes, not one of them until Autolykos of Pitane attempted to point out through hypotheses, and yet Autolykos himself was not able to. His dispute with Aristotheros proves it. What I mean is that stars at one time appear near and at other times as going away from us. For in the case of some stars this is manifest to sight. For both the so-called star of Venus and the star of Mars[32] appear at the middle of their retrogrades many times as large, so that on moonless nights Venus makes shadows fall from bodies. phenomena to end of quotation The moon is also manifest to sight itself as not always an equal distance apart from us since it doesn't always appear to us as having the same size given that the same conditions hold with regard to its being observed. Nevertheless, when we watch more carefully with instruments the same thing seems to be the case since at one time an 11 finger and at another 12 finger drum is placed an equal distance from the observer and blocks it out to the sight, **[505]** so that his line of sight doesn't fall on it. In addition to these, what happens in total eclipses of the sun also bears witness to what we've said and counts as evidence of its truth in this matter. For whenever its center and the center of the moon as well as our viewpoint are aligned what happens does not always appear alike, but sometimes the sun itself is enclosed by the cone which encloses the moon and has our sight at the apex (sometimes it even lasts for some time without appearing to us), and sometimes it falls so short of this so that a rim is left appearing during mid-eclipse.[33] Thus it would be necessary that the apparent difference in magnitudes is due to the inequality of distances rather than from nearby things in the air. What happens in the case of these which is evident to sight is also likely to occur to the others, even if it is not in full view. And not merely likely, but also true, if in fact their daily motion appears anomalous. But no difference in their apparent magnitudes comes to us since there is not much difference in their movement up and oppositely, which in fact mathematicians are accustomed to calling 'movement in depth'.[34] Moreover, they did not at all attempt to preserve this, with the result that they did not display its daily deviation in motion, although the problem is worthy of this consideration. In fact one cannot say either that the inequality of the distances of each star <at one time> to itself <at another> had escaped their notice. For Polemarkhos of Kyzikos apparently was familiar with it, although he belittled it as not being observable since he preferred the position of the spheres themselves about the middle itself within the whole. And in the Physical Problems, Aristotle raises another objection for the hypotheses of the astronomers from the fact that the sizes of the planets do not appear as equal. In this way he was not altogether satisfied with the unwinding spheres, even if the claim that spheres which are homocentric with the whole move about its middle won him over. **End Sosigenes**

However, from what he also says in Metaphysics Λ, he clearly is not one to consider that matters concerning the motions of the planets were described adequately by

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31 Cf. also 113.6-12 for Simplicius on the shape and distance of the moon.

32 Throughout, the planets are called "the star of X", although I have translated them conventionally as "X". However, here the passage draws attention to the labeling of the stars. Note that the standard names for the planets in ordinary Hellenistic Greek were not the conventional names of the dieties, which derive from Babylonian practice. Mars is the "fiery star", while Venus is "the light bearer" or "the evening star". Calling Mars "the star of Ares" or whatever may indicate that in accord with contemporary syncretism of Babylonian practice, Plato and Aristotle were associating the planets with the respective gods, although the Babylonians would identify them with

previous and contemporary astronomers. And so he does say this in some fashion (Met. Λ 8.1073^{b}11), "And so now we are saying for the sake of understanding what some of the mathematicians say, so that it may be possible to suppose in our thought some determinate number, but it remains **[506]** that it is necessary that when we seek out some things and inquire from those who seek out other things, if something different from the things now said should appear to those who work on these things, we must love both but follow the more precise." But also, after enumerating the totality of motions in the same book, he concludes (Met. Λ 8.1074^{a}14), "Let the multitude of motions be so many so that it is reasonable to suppose that the realities, the unmoved principles, and the observables are so many. For let us hand their necessity over to those who are more able to say." And so, the expressions "let there be…" and "it is reasonable…" and "leaving to others more able" indicate his uncertainty in these matters.

506.8-507.8

Text 7n

Source unknown

Source Porphyry

Source Ptolemy

And so if we take Aristotle's advice, we must rather follow those who came later as better preserving the phenomena, even if these do not preserve them perfectly either, in as much as the others did not know so many phenomena since the observations sent out from Babylon by Kallisthenes had not yet reached Greece until after Aristotle set him this task (Porphyry relates that these observations are preserved for a period of 31,000 years (Moerbeke: 1,900) up to the time of Alexander of Macedon), nor were they able to display through the hypotheses as much as they knew. Ptolemy[35] blames them also for introducing such a multitude of spheres for the sake of joint restoration alone of the seven planets with respect to the revolution of the non-planetary stars and for their claiming that the surrounded spheres are responsible for the joint restoration of the spheres surrounding them and that the last are responsible for the joint restoration of those above them, although nature always makes the higher things responsible for the motion of the lower. For in our own case, the impulses for motion are transmitted from above from the ruling part through the nerves to all the organs. But I myself do not understand why they arrange the first sphere for each star as moving similarly and equal in speed with the non-planetary sphere and jointly restoring with the non-planetary sphere all the spheres after it up to the sphere which has the star. For if the sphere lying above transmits to those below it the form of its own motion, why do we not say that since the non-planetary sphere is most powerful and dominant over all, it jointly restores all those under it by itself? It would be necessary for some to be different in respect of their having a motion in longitude and latitude, given that these spheres are different for each star. **[507]** Yet how is it that the joint restoration with the non-planetary sphere, which is the same for all the spheres, would not be appropriate for the revolution in the same sense of the non-planetary sphere, but instead there was a need to have spheres with this motion for each star and for the spheres unwinding them, according to Aristotle? Perhaps they might say that, even if they restore together with the non-planetary sphere with the same motion as that sphere by moving from the risings (east), since they are different in size they also have a speed which is altogether different. And so how plausible would it be that they be separated off without being bound together by one non-planetary sphere and so should move with different motions?

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the gods. On the issue of the divinity of stars in traditional beliefs, cf. Aristotle, De caelo, inter alia, A 3 270^{b}4-9, B 1 284^{a}11-12.

33 For Sosigenes on annular eclipses, cf. also Proclus, Hypotyposis astron. posit., Ch. 4. 98.2-99.1. These passages are important given Ptolemy's denial of annular eclipses.

34 The earliest extant use of this terminology is probably the Keskinto Inscription (ca. 100 BCE). Contrast Arist., De Caelo B 2.

35 Planetary Hypotheses ii., 111 ff. (trans Kroll; Leipzig: Teubner, 1907).

507.9-12

Text 7o Source Iamblichus possibly Nichomachus

And so, contemptuous of the hypothesis of unwinding spheres, especially due to the fact that it does not preserve the difference in depth and the anomaly of motions, those who came later rejected the homocentric unwinding spheres, but hypothesized eccentrics and epicycles. That is if the hypothesis of eccentric circles was not thought up by the Pythagoreans, as some others relate, especially Nikomakhos and Iamblikhos following Nikomakhos.[36] In order for us to get an insight into the usefulness of these hypotheses in producing our study on the heavens, let there first be displayed as in the diagram [below] the hypothesis of the eccentric which is set against the hypothesis of the homocentric.

507.18-507.25

Text 7p Source either Sosigenes or Alex. or Simpl. a very bad argument (taken from somethin g else) which 'proves' that homo-centric models cannot handle anomaly in motion, although the author needs merely motion in depth

Let there be conceived (see Simplikios, Diagram 2.1) a homocentric circle through the middle of the zodiac ABGD with center E on which we suppose our viewpoint is and with diameter AEG. Accordingly, if the star makes a uniform passage from A to B on circle ABGD, it is clear that with our viewpoint occurring on center E, if we conceive the light ray falling from it to the star as straight line AE, then this will move about it uniformly and the star, as it were, appears as both making a uniform passage and maintaining an equal distance from us.[37]

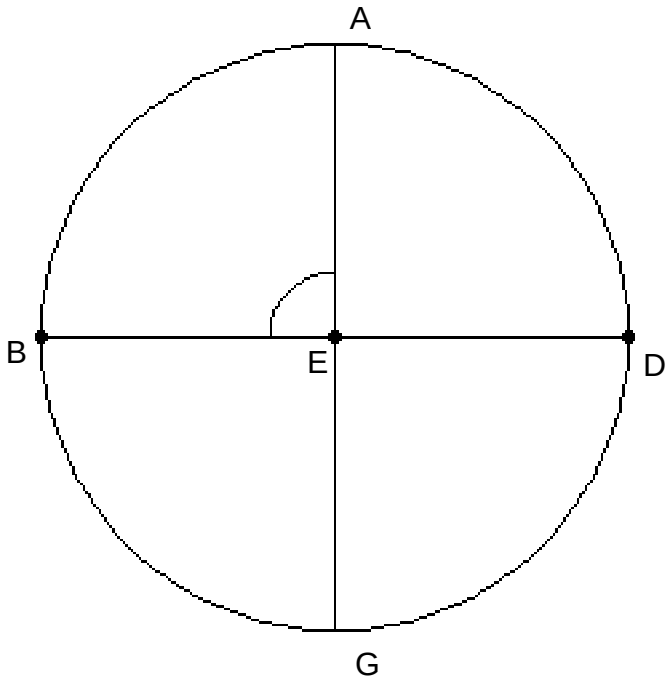

Figure 2.1

[36] There is no need to infer from this remark that Iamblikhos wrote a commentary on De caelo. The remark could be from many different sources. Clearly, Simplikios is interjecting his own material here (as with the previous paragraph on Ptolemy's objection and his own).

[37] It is a remarkable peculiarity of this discussion to 510.23 that Simplikios and apparently his source, Sosigenes, assume that on the homocentric model there is no anomaly of motion. This shows that he does not understand the models he presents earlier. This is not a trivial point. For there he only mentions latitudinal change as the effect of the third and fourth sphere of the planetary model. He clearly does not understand that more must be going on. Nor can he clearly understand why the Kallippus solar model deals with solar anomaly in the length of the seasons (497.19-22).

507.25.-508.16 **Text 7p (cont.)**

But since they are not seen in this way, but always as making an irregular passage and as having a different distance at different times as is clear from the differences in sizes (see Simplikios, Diagram 2.2), let ABGD be supposed to be a circle which is no longer homocentric with the zodiac, such that the center of the zodiac no longer happens to be at E, where we say our viewpoint is, but at Z and that ABGD is no longer homocentric with the zodiacal circle, but eccentric to it, and its apogee is A, i.e., the greatest distance from the viewpoint at Z, and the perigee is G, the least distance from the viewpoint Z. And so, if we conceive the star as being on the eccentric circle ABGD similarly moving uniformly from apogee A to B on circumference AB **[508]** and rotating around with it a straight line from the eccenter to it, then this line will move around uniformly. So let it be EB. Hence, it will happen that when a straight line ZB joins viewpoint Z to the star, the star has moved uniformly through angle AEB, but angle AZB has appeared as less. For the angle at E is an outside angle of triangle BEZ and so is greater than the inside and opposite angle at Z. But if it makes its passage from the perigee G uniformly through circumference GD, so that straight line ED also rotates with it uniformly -- let us join again straight line ZD from the viewpoint Z -- then again one passage is uniform from the perigee and is enclosed by angle GED, while the other is anomalous and appears under angle GZD. Clearly the apparent motion on the line from Z to perigee is greater than the uniform since the angle at Z is greater than the angle at E. In the case of the position of the star at B angle AEB will be uniform, but the apparent angle is AZB, and their difference is angle EBZ. In the case of the position of the star at D, angle GED is uniform, but angle GZD is apparent, and their difference is angle EDZ.

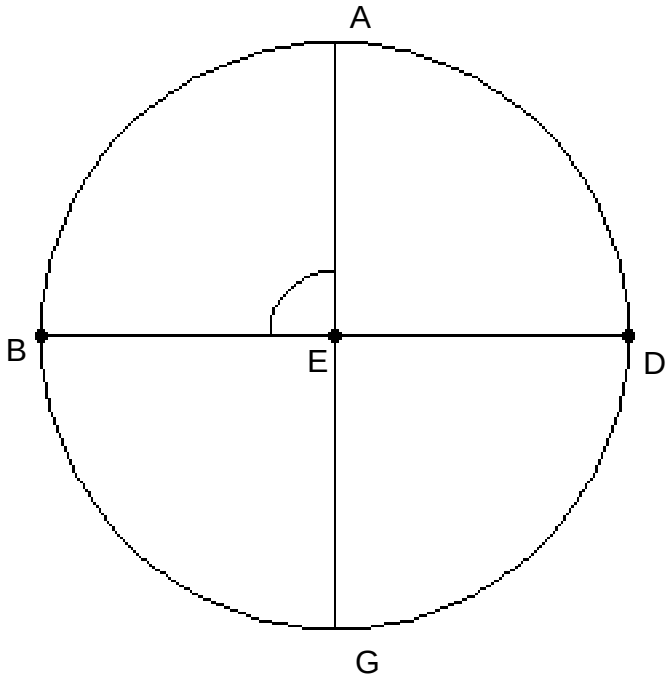

Figure 2.1

508.17-21

Although this hypothesis fits more simply with the stated goal of the mathematician, they [the proponents of eccentric models] also found another which can display the same things as the previously mentioned, i.e., in order that given the stars as moving uniformly they should appear as traversing anomalously the circumferences of the zodiacal circle.

508.22-509.12

note the version of eccentric models shown equal to epicycle models

For (see Simplikios, Diagram 2.3) let circle ABGD be again conceived as homocentric with the center E of the zodiacal circle, where again our viewpoint is, but the star does not make its motion on it, but on the so-called circular epicycle ZHQK having its center always at A on the circumference of circle ABGD, with the result that the star becomes similarly furthest from the earth at Z and nearest at Q. And it is clear that whenever the epicycle has moved uniformly through circumference AB and comes to be at B, again with EB rotating uniformly with it, but the star is moved uniformly again from perigee Z to H and makes its passage ZH -- we join straight line EH from the viewpoint E -- then the star will have rotated uniformly **[509]** again by the epicycle through circumference AB, i.e. angle AEB, but appears as moving through angle AEH which is greater than the uniform angle, and their difference is angle BEH. Whenever from Z to the apogee it makes its passage not to H but to K, angle AEB again will be of the uniform passage, but angle AEK will be that of the apparent passage which is less than the uniform, and their difference is KEB. Thus this sort of hypothesis can display both greater and smaller passages of stars at stellar positions further from the earth They are clearly greater when the star makes its passage from apogee of the epicycle to positions on the circle, and less when it moves oppositely. But hypothesis of the eccentric always makes the apparent motion at the places further from the earth less than the uniform motion, since the apparent angle AZB is always less than the uniform AEB.

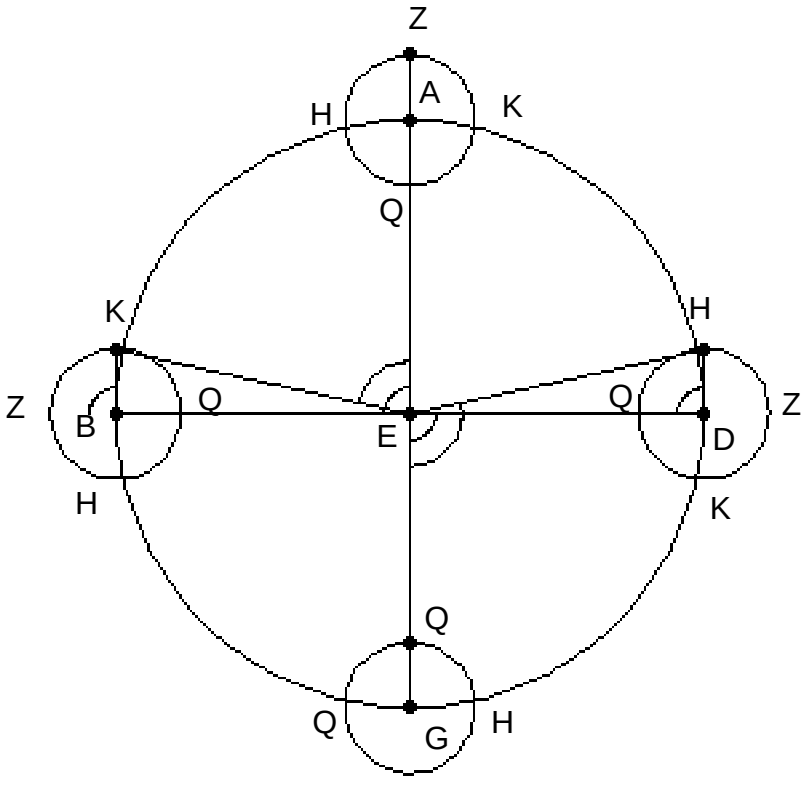

Figure 2.3

509.13-510.23 **Text 7q**

Either of these hypotheses presents the astronomical goal if it is assumed individually, except that in the case of the moon, [mathematicians] need both hypotheses composed. For they suppose the epicycle carrying the moon moves on an eccentric circle, so that the phenomena are preserved by this. These hypotheses are also simpler than the earlier ones without needing to fashion so many heavenly bodies, and they preserve the phenomena, besides others especially the phenomena in depth and the anomaly, [38] but they also do not preserve the axiom of Aristotle which requires every circularly moving body to move about the middle of the whole. But the mentioned solution to the difficulty responsible for upsetting all these arguments in the end has no standing either. For the lack of equality still has no standing, if in fact what was said no longer is true, since the first movement is one and moves many of the divine bodies, but although the other spheres are many, each moves one [divine body] alone. For the motions prior to the last and the one holding the star do not move many bodies. And **Sosigenes** derives these absurdities from these hypotheses as he does not like the hypothesis of unwinding spheres for the reasons mentioned earlier. But those who believe that even the stars are ensouled and have their own motion must object to the first. For these are not merely parts of the heavens, but also each is a whole in itself. Hence, a truer axiom would be one which says that every circularly moving body moves about its own center, [39] so that it is true to say that **[510]** as many of the heavenly bodies as have as their middle the middle of the whole move about the middle of the whole, but as many as are more particular and outside that middle move about their own middle, just as do the stars and epicycles and eccentrics, if in fact there are also such bodies in the heavens. These move about the middle of the whole even if they don't do it with their particular motion, but with the motion of the sphere which both carries them and is homocentric with the whole. Also, by this, even the argument of Aristotle would be true since every circularly moving body moves about the middle of the whole, unless someone adds that it moves [about the whole] according to its own particular motion. The solution to the difficulty will have partial standing even in the case of these hypotheses. For it will perhaps be true to say even in the case of these that nature is unequal and makes a certain arrangement by presenting many bodies with a single motion and many motions for a single body. For even if each moves with one motion of its own, but also everything under the non-planetary sphere moves with the motion of the non-planetary sphere, and the epicycles move with this and with the motion of the homocentric or eccentric circles, the star too which he called one body moves with the motion of the epicycle, the motion of the homocentric or eccentric, and the motion of the non-planetary star. Moreover, the eccentric circles would not be moving in a circle if in fact they do not move about the middle, but about a position outside the middle. Also in their turning they occupy place and leave behind void and so force it to exist, and the shape will be peculiar given that the inside always cuts off a part of the outside. We will, in fact, escape all these problems by fitting eccentric spheres inside homocentric ones and in saying that the homocentric sphere moving about its own center rotates the eccentric which is itself moving about its own center. We will say all perfect spheres without fear that in those cases one body goes through another.

echoes of Ptolemy?

Is Sosigenes the source of Text 7p?

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38 The anomaly is the synodic motions of the planet.

39 Is Simplikios (or Sosigenes) ignoring the equant or is he unaware of it? If Simplikios is closely following Sosigenes, the latter is plausible.

510.24-35 **Text 7r**

Sosigenes cleverly raises not a few other astronomical difficulties also against these hypotheses, which may be examined in another discussion. But now, we have thoroughly examined the arguments about the heavens and heavenly motions, in establishing the demonstrations through which [the stars] were shown as circular and uniform and ordered, since they appeared as anomalous as well as having upward and downward paths. So it seems that we have provided for our reflection certain hypothesized things by which through circular, uniform and regular motions the ancient astronomers as well as those who came after them preserved the phenomena. And so if this is more appropriate to accounts concerning the heavens than to accounts concerning first philosophy, no one will blame us for our large digression from the argument, if it has come at an appropriate moment. But we must go back to what comes next in Aristotle's accounts.

The following two passages from Proklos provide further information as to the contents of Sosigenes' work: **Text 8 Proclus**

Proklos is basically repeating what Ptolemy says about the apparent diameter of the sun. It follows from the remarks that annular eclipses should be impossible. This is wrong, but not for the reasons Sosigenes gives, but because the apparent diameter of the moon at apogeee may be less than the apparent diameter of the sun. Proklos, Hypotyposis astron. posit., Ch. 4. 97.1-99.4: **source Sosigenes?**

And so the apparent diameter of the sun, in its extent, is always determined with a diopter to be the same, whether the sun is at apogee or at perigee, and the diameter of the moon is determined as larger and smaller with different distances from the earth. Sometimes it appears merely as equal to the diameter of the sun, as when the moon is in apogree on its own circle [i.e., the epicycle], i.e. when it is at full moon and in conjunction, as in solar eclipses. From this it is clear that if this is true, what **Sosigenes** the Peripatetic related in the books On Unwinding <Spheres> is not true, namely that when the sun is in eclipses at its perigee, it is seen without being completely occluded, but that with the edges of its circumference it exceeds the circle of the moon and lights up without being impeded. For someone who accepts this, either the sun will produce a difference in the apparent diameter or the moon at apogees will not fail to make a difference in the apparent diameter when a diopter is used in relation to the diameter of the sun.

The following testimonium need not be from Sosigenes' book On Unwinding <Spheres>, but is consonant with the discussion of Simplicius, 506.8ff. This may well be the largest ancient value for the Great Year. Proklos, In Rem Publicam ii 23.1-24.5: **Text 9 Proclus source Sosigenes?**

21. **Sosigenes** computed the perfect year from the fourth myiad 34, from the third myriad 43<..>, from the second myriad 7876, from the first myriad 3836, and from years 6<70 or 09>.[40] He computed this from the joint return to the same position of the seven spheres. For, he took the precise return to position of one planet and of another and then found the [least] number measured by these, and then he added in a third, and so forth. In this way, he found the number measured by all of them. In this way, some set out procedures, not merely for the twelve year [zodiacal cycle] of Jupiter, but also of Saturn and Jupiter, and with each helping to complete different values according to its own period along with the period of some other or with the others. [41]

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[40] The n'th myriad is 10000^n. Sosigenes' number is either 344300787638360670 or 344300787638360609 + x * 10^{12} where x is a two digit Greek number (where 0 isn't a digit), i.e., $11 \le x \le 99$ and x is not n*10. There are several plausible candidates among them: 344341787638360670, which is divisible by 54787 = (365 + 1/4 1/300)*150. I shall discuss these in a future article.

[41] Namely, the procedure would be to find the least common multiple, e.g., of 29 1/2 (Saturn) and 12 (Jupiter), and then the least common multiple of this (708) and the period for Mars (such as 79/42), and so forth.