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Simplicius' Commentary on Aristotle, *De caelo* 2.10–12: An Annotated Translation (Part 1)

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Introduction

If there is a single text that has proven to be the bedrock for the modern understanding of early Greek astronomy, it is Simplicius' commentary on book 2 chapter 12 of Aristotle's treatise, *De caelo*. Simplicius' remarks, which are effectively an elaboration of what he supposes Aristotle to mean in *Meta.* Λ 8, are almost always accepted as gospel in their broad outlines. Take any recent history of early Greek astronomy you please and you will find that its author immediately turns to Simplicius as the source clarifying what Aristotle writes in this chapter of his *Metaphysics*. Indeed, the main challenge scholars perceive in Simplicius' commentary is to tease out and reconstruct the underlying mathematical theory which would make it all 'true'. Such naïveté is breathtaking. Few who read Simplicius and understand his historiographical project—a search for a truth that Aristotle's text is supposed to embody rather than a study of the text itself on its own terms[1]—would elevate him to a position of such unquestioned authority. And those who have reflected on the often intractable problems in assessing the truth of ancient reports or *testimonia* in the sciences will quite naturally decline to take Simplicius at his word in this matter. I recognize, of course, that it is customary to detect errors in Simplicius' account and to attribute them to either Aristotle or Simplicius; but this, I fear, amounts typically to little more than a demonstration that we moderns can be speciously clever while taking what Simplicius writes for granted.

I have written at length elsewhere that Simplicius' comments on *De caelo* 2.12 do not constitute an account of what Aristotle meant in *Meta.* Λ 8 that we should accept today as properly historical.[2] There is, after all, no extant Greek or Latin text written before the late second century BC that shows any knowledge of the

[1] See Wildberg 2005 for an excellent overview of the commentary tradition in the fifth and sixth centuries AD.

[2] See, e.g., Bowen 2001, 2002.

planetary phenomena of station and retrogradation which is so central to Simplicius' commentary. There are also ample signs that Simplicius' remarks about the history of early astronomy are not a report but a reconstruction occasioned by what Aristotle writes in *Meta.* Λ 8 and the need to explain why the homocentric planetary theory outlined there was later abandoned by Aristotelians. Moreover, *Meta.* Λ 8 is itself underdetermined so far as its presentation of this homocentric theory goes. Indeed, there are other interpretations of this presentation that fit far better than Simplicius' with what we can find elsewhere in Aristotle's writings and in documents by other writers of the fourth century.

That scholars today persist in reading *Meta.* Λ 8 and other early texts as indicating knowledge of the planetary stations and retrogradations is a puzzle. One only wishes, when these scholars have elaborated their interpretations of *Meta.* Λ 8 and of the other related texts written before the late second century that concern the planetary motions, that they not stop here as if their work as historians were done. Obviously, it will not be enough if they simply adduce relevant *testimonia* by later ancient writers. Not only are these *testimonia* few in number and date to a time *after* the characteristic planetary motions were duly understood, they typically prove on critical examination to be either ambiguous or anachronistic in the same way as Simplicius' account is. Consequently, any appeal to such *testimonia* without critical argument in defense of their historical validity is pointless. Indeed, the burden must fall on these scholars to demonstrate that *Meta.* Λ 8 and the other early texts *must* be read in this way. For, absent such proof, all one has is the fallacy of imputing to a writer the perceived consequences of what he writes. Of course, making such a proof will be hard work. Even those sharing the general view that the Greeks of the fourth century were aware of planetary stations and retrogradations do not agree about how these phenomena were understood or explained.[3] In addition, there are my own arguments not only that these texts *may* be read without supposing such knowledge, but also that they *should* be read without such a supposition, given the contemporaneous evidence of astronomical theory. And finally, there is the largely unrecognized problem that, even if Simplicius' history of astronomy in Aristotle's time is anachronistic, it has a simpler interpretation than the one first propounded in the 19th century by Schiaparelli [see 1925–1927] and elaborated to this day. Granted, these scholars may wish to excuse themselves from the charge of wrongly imputing to Simplicius what they perceive as the real meaning of his text, by claiming that Simplicius is preserving material from earlier sources that he does not understand. But should historians today assent to reading an ancient commentary in a way that makes the commentator irrelevant, and should they do this in the expectation that the interpretation offered reflects the thought of some putative source from whom nothing survives for confirmation? My own view is that

[3] Cf., e.g., Heglmeier 1996, Mendell 1998 or 2000, Yavetz 1998.

compounding such a misreading of an ancient literary genre with such untestable faith or, if you will, unassailable credulity, may have numerous outcomes but that historical knowledge will not be one of them.

Few modern historians have examined what Simplicius actually writes—the great tendency is to rely on some learned summary such as that supplied by Heath [1913] who makes accessible in English the pioneering work of Schiaparelli. Accordingly, I here present Simplicius' account of *Meta.* Λ 8 so that readers may begin to get their own sense of what is at issue. To this end I have translated Heiberg's edition [1894] of Simplicius' commentary on the three narrowly astronomical chapters of the *De caelo*, and have supplied my translation with annotation that is intended primarily to clarify the technical, scientific meaning.

Given the exigencies of publication, this annotated translation will come in two parts. The first, presented here, is devoted to Simplicius' commentary on *De caelo* 2.10–11. These chapters in the *De caelo* raise stock issues in astronomy; and it is valuable, I think, for readers interested in Simplicius' account of planetary theory in 2.12 to see and assess just how he deals with them. Indeed, not only does Simplicius' commentary on 2.10–11 show him drawing on a tradition of technical writing for novices and philosophers that goes back to Geminus and Cleomedes,[4] it also shows him going astray on fundamental points in elementary mathematics. And this is surely important for our interpretation of his commentary on 2.12.

The annotation itself is, as I have said, intended to assist the reader with information that may be needed to make sense of the text. My main aim is to allow access to Simplicius that is as little encumbered by my interpretative intrusion as is feasible, since my hope in this publication is that the reader will confront Simplicius for himself by himself, so far as this is possible in a translation. Thus, I do not engage the detail of the interpretations offered by those who assume that the early Greeks were aware of the planetary phenomena so central to Simplicius' account of *Meta.* Λ 8.[5] Still, there is a question about just how much annotation is needed by readers of this journal, and I hope that I have not erred too much in following my natural disposition to say less.

Simplicius' Greek is typical of scholastic commentary: elliptical, crabbed, and technical. I have tried to deal with this by supplying in square brackets what is missing whenever this seemed necessary or likely to make the meaning easier for the reader to grasp. At the same time, I have tried, so far as it is reasonable and I am able, to capture Simplicius' technical vocabulary and to preserve the logical structure of his sentences. I have not, however, been a slave to the dogma that

[4] On Cleomedes' readership, see the introduction in Bowen and Todd 2004.

[5] And it is unlikely that I will engage it elsewhere until there is offered good argument for the historical truth of this assumption. The alternative would be much like entering someone's house and discussing over tea its structure and décor, after pointing out to him that it is on fire.

key words in Greek must have unique renderings in English.[6] Still, though I trust that the resulting translation is sufficiently reliable to support fairly close work on the many questions of Simplicius' meaning and method, I confess that I will not be disappointed if readers throw up their hands and turn to the original to see what they can make of it on their own. In fact, I have included page and line numbers of Heiberg's edition of the Greek text in the margin of my translation for this purpose. (My rule in positioning the numbers was to put them beside the line in English where the first word of the line in Greek is translated.) In the same spirit, I have also put in italics those passages from Aristotle's writings (mostly the *De caelo*) that Simplicius quotes without specific notice, along with a footnote giving the proper citation.

This translation has benefited greatly from the generous criticism of earlier versions offered by Bernard R. Goldstein and Robert B. Todd: they have saved me from numerous mistakes and infelicities, and I am most pleased to acknowledge this. I am also very grateful to John. P. Britton, Dave Herald, Heinrich von Staden, Christopher Walker, and Christian Wildberg for answering detailed questions about the sense and background of various troublesome passages in Simplicius' commentary. And to keep their goodwill, I will also affirm the usual caveat. These scholars are not responsible for any errors or confusions that the reader many discern in my translation and notes: those that remain in spite of my best efforts are mine alone.

In addition I thank my brother, William R. Bowen, and the two anonymous readers for *SCIAMVS*: their comments and suggestions have proved most helpful. And finally, I am very pleased to record my gratitude to Ken Saito, the Managing Editor of *SCIAMVS*, for his unflagging interest in this project and his encouragement as I pursued it. That my annotated translation appears in *SCIAMVS* is ample proof of his very kind support and his patience with a historian whose sense of time seems limited to the past.

[6]See, e.g., p. 27n2 (on ἄστρον, ἀστήρ) p. 28n5 (on οἱ μαθηματικοί), p. 29n6 (on καταλαμβάνω). The general point here is that translating each (technical) term in Greek by a single term in English is only a desideratum, and one that must be tempered against the requirements of clarity in rendering the meaning of the Greek terms.

Translation

In Arist. de caelo 2.10

291a29–b10[1]

> *Let us theorize about the ordering of the heavenly bodies*[2] *—the way in which each moves in that some are prior and others posterior—and how they are related to one another in their distances, on the basis of [works] on astronomy, since it is discussed [there] sufficiently. It turns out that the motions of each are in a ratio with regard to their distances*[3] *in that some [motions] are faster and some*

[1]To aid the reader I include a translation of the passage in full from Aristotle that Simplicius is to comment on. For his part, Simplicius gives only the opening and closing words of these passages in his lemmata.

Chapter 2.10 of the *De caelo* opens [291a29–34] with a question that is relevant to the two characteristic motions known to belong to any planet in Aristotle's time, its diurnal motion and its motion in longitude along the zodiacal circle; and it seems to affirm a proposition that is arguably true of both—namely, that there is a direct proportionality between the motion of a planet and its distance. (Presumably, the diurnal motion would be viewed as a linear speed, since the diurnal *angular* speeds of the planets are all the same and since their diurnal linear speeds do indeed vary directly with the distance of the planet in question from center of the Earth.) As 291a34 ff. makes clear, however, Aristotle is really thinking of the planetary longitudinal motions. In this case, the motion of a planet is faster if the planet completes its eastward circuit in longitude and returns to a given fixed star in a shorter time, that is, if it has a shorter sidereal period. Moreover, the distance to which this motion is proportional is to be that from the celestial sphere, not from the center of the Earth. There are two points worth noting here. First, this direct proportionality of a planet's longitudinal motion to its distance from the fixed stars is simply not the same as an inverse variation with the distance of the planet from the center of the Earth. Second, there is not enough information given here to decide whether Aristotle has in mind anything as specific as linear or angular speed when he discusses the planetary longitudinal motions.

[2]*De caelo* 291a29 αὐτῶν: the antecedent is τὰ ἄστρα at 291a27. In general, Aristotle and Simplicius use τὸ ἄστρον and ὁ ἀστήρ to designate a star whether it is fixed or wandering (i.e., planetary). Usually the context makes clear whether they are thinking of one or the other kind of star; and when it does I translate these terms accordingly by '[fixed] star' and '[wandering] star' or '[planetary] star' rather than simply by 'star', in the interest of clarity. There, however, occasions when they mean to refer to both kinds of star at once, as Aristotle does at 291a26–28 and here. And again rather than render these occurrences simply by 'star', I think it clearer to use 'heavenly body'. After all, this is standard English usage and it will serve well here, if the reader bears in mind that not all heavenly bodies are fixed or wandering stars.

[3]*De caelo* 291a31–32 κατὰ λόγον: this phrase is qualified by a dative of respect, τοῖς ἀποστήμασι. For both Aristotle and Simplicius, two magnitudes can be in a ratio only if they are of the same

> *slower. That is to say, since it is supposed that the outermost revolution of the heavens is simple and fastest, and that the [motions] of the others are slower and more numerous—for each moves in a direction opposite to the heavens along its own circle—it is actually reasonable that the [body] nearest the simple and primary revolution goes through its own circle in the longest time, and that the one that is farthest away in the least time; whereas of the others the nearer always [goes through its own circle] in more time and the farther in less time. The reason is that the one that is nearest [the outermost revolution] is dominated [by it] most of all and the one that is farthest [is dominated] least of all on account of its distance; whereas the intermediate [bodies] are actually [dominated] in the ratio of their distance,*[4] *just as the scientists*[5] *in fact prove.*

470.29 Anyone making statements about the heavenly [bodies] also used to have to make

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kind: cf. Euclid, *Elem.* 5 defs. 4 and 5.

[4] *De caelo* 291b8–9 κατὰ λόγον τῆς ἀποστάσεως.

[5] *De caelo* 291b9–10 οἱ μαθηματικοί. A μάθημα is a thing learned, a body of learning or knowledge, and thus a science. The noun itself is formed from the verb μανθάνω (to learn whether by study, practice, or experience) and has the force of the neuter perfect passive participle treated substantively. Hence, the basic sense of οἱ μαθηματικοί is 'men of learning or science' or even just 'scientists'. In the present instance, the bodies of learning in question are sciences and so I have used the general term, 'scientists' even though there is reason to think that the science in question is astronomy and thus that 'astronomers' may well be warranted. The broad issue here is how the division of the sciences in the fourth century BC mapped onto the distinction of their practitioners (both living and theoretical), and in dealing with it I have decided to adopt a translation that prejudges as little as possible and yet is still intelligible.

In any case, rendering οἱ μαθηματικοί by 'the mathematicians' is not helpful at all. First, Aristotle's understanding of what a μαθηματικός is differs from our notion of a mathematician; and so such a translation really does tend to mislead. Further, though there is evidence that the term μάθημα was paradigmatically applied in this period to any science that uses mathematics, it does not follow by any means that such a mathematical science was viewed simply as mathematics, as a branch of mathematics such as arithmetic or geometry, or even as applied mathematics. At least such an inference does not capture how the sciences were understood and differentiated in the fourth century BC [see, e.g., Plato, *Resp.* 7 and Aristotle, *An. post.* 13 with Bowen 2004]. As for Simplicius, his usage tends to follow Aristotle's especially when he is attending closely to what Aristotle writes [cf. Heiberg 1894, 454.12]. At other times, however, notably in his commentary on 2.12, Simplicius seems to address the same people as οἱ μαθηματικοί and as οἱ ἀστρονόμοι or οἱ ἀστρολόγοι (both translated there by ' the astronomers'). Still, even in these instances, I have chosen to preserve the linguistic distinction at least by continuing to translate οἱ μαθηματικοί by 'the scientists', if only to assist the reader in thinking about the meaning of ὁ μαθηματικός and its role as a marker in the development and organization of the sciences in antiquity.

statements about the ordering of the spheres and [planetary] stars in respect of their position; [specifically, he used to have to say] which ones are prior (that is, nearer the fixed [sphere]) and which ones are posterior (that is, nearer the Earth), and moreover, of course, how they are related to one another in respect of their distances (which are compared in reference to the Earth) on the basis of which the 471.1
ratios of their sizes are in fact known.[6] Thus, he says, of these matters '*let us theorize on the basis of [works] in astronomy*',[7] since proof has in fact been given there of the ordering of the wandering [stars], that is, [proof] of their sizes and distances—Anaximander[8] being the first to devise an account of their sizes and distances,[9] as Eudemus[10] reports in attributing the ordering of their position to the Pythagoreans first. The sizes and distances of the Sun and Moon have been known even to this

[6]471.1 οἱ τῶν μεγέθων λόγοι. Simplicius contextualizes 2.10 by referring to an ancient concern about the sizes and distance of the *spheres* (or circles) on which the fixed stars and the planets move. Though he does write of the sizes of the Sun and Moon at 471.6, the issue for him is not what we call the magnitude or apparent size of a given fixed star or planet.

471.1 καταλαμβάνονται. The verb καταλαμβάνω has a wide range of meanings but in this chapter it generally indicates seizing, taking, or receiving. When the 'taking' is done by the mind, it signifies comprehending, detecting, determining, understanding, accepting, and so forth. It is difficult to find a single translation that works well in all occurrences of the verb and of the related substantival and adjectival forms (κατάληψις, καταληπτικός, respectively). Thus in 471.1 the passive καταλαμβάνονται broadly means 'are understood', 'are made known', or even 'are ascertained'. But given that the objects understood are numerical ratios, English usage would naturally incline here to 'are known', given that what is understood is their value. Cf. καταληπτή ('be knowable') at 476.18. Yet, in 471.7–8 ἀπὸ τῶν ἐκλείψεων τὴν ἀφορμὴν τῆς καταλήψεως λαβόντα, καταλήψις indicates a process of detection or determination by which quantitative values are known and the aorist participle from λαμβάνω, a simple receiving (if aspect predominates) or a having received and, hence, just having (if tense is important). In 474.19, however, κατείληπται signifies detection that here borders on discovery and so is perhaps better rendered by 'has been found'. In sum, it seems to me prudent to render this important verb and its cognate forms as the context requires rather than to impose a single meaning.

[7]*De caelo* 291a31–32: the text set in italics is a quotation of these lines from the *De caelo*. I will use this convention whenever Simplicius actually quotes the text of Aristotle.

[8]Anaximander of Miletus (sixth century BC, died after –546).

[9]For what little they are worth, the ancient reports about Anaximander's account suggest that he was thinking of the diameter of the rotating planetary rings of fire as well as of the diameter of the opening in these rings through which the fire is visible, Earth's diameter being the unit of measure: see Kirk, Raven, and Schofield 1983, 135–136.

[10]Eudemus of Rhodes (late fourth century BC). For discussion of Eudemus' book on earlier Greek astronomy, see Bowen 2003, 315–318.

day in that they have the means of their determination from eclipses[11]—and it was reasonable that Anaximander discovered these too—and [the sizes and distances] of Mercury and Venus [have been known] from their conjunctions[12] with [the Sun and Moon]. The sizes and distances of these [planets] have been made more precise by those who come after Aristotle and quite perfectly so by those associated with Hipparchus, Aristarchus, and Ptolemy.[13]

It turns out, he says, that the motions are in proportion to their distances because [planets] that are nearer the Earth, like the Moon, move faster, whereas those that are farther move more slowly in the proportion of their distances.[14] Now then,

[11]As they are determined, for instance, in the third century treatise, *De magnitudinibus*, by Aristarchus. This is not how Ptolemy computes the sizes and distances of the Sun and Moon in *Alm.* 5.13-16.

[12]471.9 μεταπαραβολῆς: according to the Liddell, Scott, and Jones 1968 *s.v.*, this term means 'conjunction' and this is fine here, though it would be more precise to speak of the 'occultations' of the planets by the Moon and of their 'transits' of the Sun.

[13]See note 11, above.

471.11 τῶν περὶ Ἵππαρχον καὶ Ἀρίσταρχον καὶ Πτολεμαῖον. Locutions of the type, οἱ περὶ Ἵππαρχον, (literally, 'those around Hipparchus') are difficult and the translation proposed here is offered with due diffidence. (Cf. Toomer 1984, 137n19 on the obscurity of such locutions in the *Almagest*.) In general, though οἱ περὶ Ἵππαρχον is often translated 'the school of Hipparchus', this may suggest too much both about the organization of the thinkers in question and about their doctrinal coherence. The alternative, 'the followers of Hipparchus', would be preferable, though perhaps not as good as 'those associated with Hipparchus' or just 'the Hipparchans'. As I have pointed out elsewhere [cf. Bowen and Goldstein 1991, 251], one should bear in mind that the phrase may mean only those who share certain assumptions or procedures with Hipparchus, whether they are contemporary with him or subsequent to him. In any case, when this sort of translation is appropriate—as it may be here—we should not take for granted that what is attributed to the Hipparchans must also hold of Hipparchus: such an inference requires more evidence than the mere phrase οἱ περὶ Ἵππαρχον, since there are many cases in which the 'followers' abandoned their 'hero'. Such is the case with Plato and his 'followers', for example.

Still, there is a possibility in this instance that τῶν περὶ Ἵππαρχον καὶ Ἀρίσταρχον καὶ Πτολεμαῖον amounts to no more than 'by Hipparchus, Aristarchus, and Ptolemy', since the οἱ περὶ + genitive locution may also be a formulaic or urbane way of referring to a single person. And one may well incline to this translation given the evidence of Aristarchus' *De mag.* and Ptolemy's *Alm.* 5.13–16. Nevertheless, it is important to recall that Plutarch, for instance, cites Aristarchus and his treatise at *De facie* 925c and so might well have been viewed as an associate of Aristarchus by Simplicius (though Simplicius does not name Plutarch anywhere in his commentary on the *De caelo*).

[14]Simplicius confuses Aristotle's position. For Aristotle, the motions and distances of the planets are proportional when the distances are taken from the sphere of the fixed stars. But Simplicius, perhaps out of his desire to speak of planetary distances and *sizes* as well, mistakenly assumes that

this [claim], which was appropriately introduced, justifiably raised a problem for his
account of the ordering, that is, of the distances, namely, why the [planets] circling
near the Earth move faster and the [planets] that are higher and come closer to
the fixed [sphere] move more slowly, just as the [star] of Saturn which returns in
position after 30 years [moves more slowly] than the Moon which makes a revolution
in a month. In fact, the problem could be initiated from two [considerations. First,]
from size, since a larger body performs its proper motion faster, as Aristotle himself 20
said,[15] and since the containing body is always larger than the body contained.
How, then, are the outer [motions] not performed faster in the ratio of their size or
distance, but to the contrary are performed more slowly? Yet [second], the problem
must also be raised from proximity or distance to the fixed [sphere]. For, if the fixed
[sphere] performs the fastest motion of all the spheres, it is a consequence that the 25
[bodies] nearer to it move faster than those that are farther in the ratio of their
distance; and if the Earth is immovable by nature, the [planets] that are closer to
the Earth would have to be slower than those at a greater distance and this again
in the ratio of their distance.

Now, in solving these problems handily he says that, since the fixed [sphere]
performs a single motion that is fastest, I mean, the motion from the east, whereas 30
the wandering [stars perform] this motion as well as the one in the opposite direction,
it would be reasonable that the [wandering star] nearest the fastest revolution[16]
goes through its revolution opposite to [the fastest revolution] in the most time
because [this star] is dominated and resisted by it, whereas the [wandering star] 472.1
that is farthest[17] moves faster than the others because it is dominated least of all
on account of its distance, and that the ones in between actually [move] in the ratio
of their distance, just as the scientists in fact prove. What then? Do the [spheres]
that come closer to the fixed [sphere] move more slowly because they are overcome 5
by it? And yet, if [they move] by force, [they do] in fact [move] utterly contrary to
[their] nature. Consequently, [the spheres] will perform both their motions, that is,
the one from the east which they perform with the fixed [sphere] and the one from
the west, that is, their proper motion, by force and contrary to [their] nature.[18]

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the proportionality Aristotle mentions holds when the distances are taken from the center of the Earth: see note 1, above. Granted, there may be such a proportionality and the three worthies named in 471.11 certainly do construe planetary distances in reference to the Earth; but that is not what Aristotle has in mind.

[15]See, e.g., *De caelo* 289b33–290a5, though the thesis is here limited to bodies that circle around a common center at different distances in the same time interval.

[16]*scil.* Saturn.

[17]*scil.* the Moon.

[18]Here as elsewhere in the commentary on *De caelo* 2.10–11, Simplicius follows Aristotle in supposing that each planet has but one sphere. Indeed, there is no good evidence in the *De caelo* prior to

Alexander[19] confronts this problem quite well[20] when he says that the very fast motion of the fixed [sphere] is the cause of the slower return in position for the sphere of Saturn, though [that sphere] is not itself unwilling of course—for it should prefer and want this, since nothing would be better for [the spheres] or more worthy of choice than this sort of cosmic arrangement. Thus, both necessary causation and final causation coincide,[21] since there must not be only what is forced. That is, because it is best that it be so, [the sphere of Saturn has a return in position slower than the others] willingly; and because it is [a planet] close to the [sphere] that goes round in the opposite direction,[22] [the sphere of Saturn has its return in position slower than the others] out of necessity. Of course, the motions due to their influence on one another are not contrary to nature for the [planetary spheres], given that there is not any motion that is contrary to nature for them because there is not even an opposite.[23] Since all the motions which [the spheres] perform are according

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2.12 that Aristotle views the planets as having more than two motions, one diurnal and the other sidereal. Leggatt [1995, 25–26] proposes that *De caelo* 288a13–17,

> Of what has been said about the motion [of the heavens], next would be to expound that it is smooth and not unsmooth. I mean this about the first heaven and the first motion, since the numerous motions in the lower regions are in fact unified [literally: come together into one thing]

affords such evidence; but this passage is hardly conclusive. Leggatt assumes that Aristotle is referring to the compounding of several motions into a single motion in the case of each planet. If this is correct, the remark is quite illogical and may be not be an integral part of the chapter [see Easterling 1961, 145–146]. But there is an alternative reading that avoids this sort of difficulty by understanding that the many motions beneath the celestial sphere are to form just one motion and not several. Now, the only planetary motions that can sensibly be said to come all together into one are their diurnal motions. After all, each planet has its own distinct diurnal motion precisely because it has its own peculiar linear speed; and yet these speeds are such that each planet completes one revolution in the same time interval. Accordingly, on this reading, Aristotle quite reasonably declines to discuss the diurnal motions of the planets, since it will be sufficient for his purposes to deal with the diurnal motion of the celestial sphere (which causes these planetary diurnal motions).

[19] Alexander of Aphrodisias, an Aristotelian commentator, who became a public teacher of Aristotle's philosophy perhaps in Athens sometime during the period between 198 and 209 AD. His commentary on Aristotle's *De caelo* has not survived. He was a student of Sosignes (2nd century AD), a Peripatetic philosopher: cf. Hayduck 1899, 143.12–14.

[20] 472.8 καλῶς δή: perhaps, 'in an entirely correct way'.

[21] 472.12-13: literally, 'the cause in accordance with what is necessary and the cause in accordance with what is best coincide'.

[22] *scil.* the fixed sphere.

[23] This is argued in *De caelo* 1.4.

to nature for them, it must be that some motions arise from [the spheres] themselves and others arise due to their influence on one another. Consequently, even in the case of the motion which [the planetary spheres] perform because they are moved with the fixed sphere, one should say the same thing, namely, that not even this is contrary to nature for them.

But perhaps the problem still remains. For let it be the case that the motions due to their influence on one another are performed neither by force nor contrary to nature but willingly. Would it not be necessary that in all cases the spheres do indeed have proper motions[24] according to nature, since they are ensouled and share in activity, as he himself will say?[25] But, if the motions which they perform are two in number, the one from the east and the one from the west, inasmuch as [the planetary spheres] perform the motion from the east which belongs to the fixed [sphere] (given that they are carried round in this motion with it) and inasmuch as they also have the motion from the west which is itself dominated and resisted by the fixed [sphere], what proper motion can they have according to nature? Consequently, Aristotle's account has not solved the problems of how it is still true that the larger body performs its proper motion faster; and of how what is close to the fixed [sphere] (which has the fastest motion) and is plainly more akin to it (since nearness in place has been assigned according to kinship in substance) has a slower motion, whereas what is next to the immovable Earth has a faster one.

Thus, he[26] has not, I think, solved these [problems] but has conceived another cause that does not finally get away from what is forced. That is to say, even if [the planetary spheres] have this derivative motion from the east because they are moved with the fixed [sphere], nothing prevents them from performing this motion willingly, because they also have their proper motion, that is, their motion according to a proper impulse which is unimpeded[27] and proceeds according to nature, as if they were not even carried round with the fixed [sphere]. But if their proper [motion], that is, [their motion] according to nature is dominated as it is resisted, how will it be unforced?

[It will be] unless someone should say that the [spheres] which are near to the fixed [sphere] do themselves in fact have the motion from the east as their proper motion in so far as they are akin to it, and that the larger [sphere] always moves faster, given that magnitude and speed of motion are in the same ratio because there is a single union of all the spheres in a single heavenly body. However, in so far as [the

[24] 472.23 οἰκείας κινήσεις: motions that are inherent or proprietary.

[25] In *De caelo* 292a20–21: 'we must suppose that they share in activity and life'.

[26] *scil.* Alexander, presumably.

[27] 473.5 τὴν κατ' οἰκεῖαν ὁρμὴν γινομένην ἀνεμπόδιστον...καὶ κατὰ φύσιν προϊοῦσαν: or 'that is, their unimpeded motion which is according to their proper impulse and which proceeds according to nature'.

planetary spheres] possess a nature that moves in the opposite direction, the ones that come under a little way to [the fixed sphere] perform the motion akin to [the motion of the fixed sphere] faster because they remain more in the peculiar character of the fixed sphere; whereas [they perform] the [motion] of the nature which goes in the opposite direction more slowly.[28] The reason is that the [spheres] are not somehow constituted purely according to that [sphere]; just as the sphere of the Moon, which is farther from the fixed sphere not only in place but also in substance and nearer the process of becoming, performs the motion of the fixed [sphere] more slowly (inasmuch as the [Moon's] sphere is smaller)[29] and the contrary revolution faster.

It is as if you conceived in the sublunary [region] a some substantial structure that changes from air to water. Certainly, in this structure the substance that has come out a little way from the air has the motion akin to the air (I mean, motion upwards) faster than substances that have come out more [from the air]; whereas it has the motion downwards[30] slower. And in succession [the substances that come out from the air] have their speed and slowness in proportion to their kinship with the air, with force being nowhere evident but their very nature having each [motion]. But, while this sort of substantial mixture exists here [in the sublunary region] in accordance with both change and opposition, it exists there [in the superlunary region] in accordance with progression and subordination, that is, with alteration of form without opposition.[31] For it has been proven that the [motion] from the east

[28]473.15: Heiberg suspects that there may be a lacuna here and supplies in his apparatus: 'And the ones that go out more [from the fixed sphere] perform the motion of [the nature] which moves in the opposite direction faster, but the motion of the fixed [sphere] more slowly.'

It is important to remember that Simplicius is answering the question in 473.4–5 and so is really focusing on the motions of the planets from west to east.

[29]473.18 ὡς βραχυτέρα. The point seems to be that the degree to which the sphere of the Moon is constituted by nature to move eastward depends on its size which in turn varies with its distance from the sphere of the fixed stars. Simplicius is here spinning out a hypothesis that is at odds with his earlier assertion that the sizes of the planetary spheres are in proportion to their distances from the Earth [cf. 470.31–471.1] and his assumption that this is what Aristotle has in mind [see note 14, above].

[30]The motion presumably characteristic of water.

[31]The hypothesis is here formulated in terms used by later Platonists. So far as the Stoics go, Cleomedes [*Cael.* 1.115–119 (with Bowen and Todd 2004 *ad loc.*), 2.3.81–91] holds that the four elements are arranged broadly in layers of decreasing density as one moves upward [see Todd 2001]; and he locates the Moon at the conjunction of aether and air, noting that its body is made of both. He does not, however, spell out what this might mean for the behavior of the planets—for example, whether the gradation of the density of the aether bears on their sidereal periods. The only consequence he mentions is that the Moon appears rather murky.

and the [motion] from the west are not opposite motions,[32] which is in fact why the same [planet] can perform both these motions at the same time equally according to some single nature that exists by progression (if in act this argument states any truth 474.1
in [these] most difficult [matters]). Certainly, in this way the proportion of size in relation to speed[33] from the upper [spheres] to the lower [spheres] will be preserved as in a single whole, and in turn the motion of the wandering [stars] *qua* wandering (which is itself in fact a proper [motion]) will no longer have the proportion of its speed in accordance with the size [of the planetary spheres] but in accordance with the degree to which [this motion] makes evident the unique nature of the wandering [star]. [34]

Alexander is in fact convinced that, while the larger spheres are faster in accordance with their nature, the upper [spheres] move more slowly because they are hindered by the fixed [sphere], on the basis of the fact that, as he says, the spheres of Mars[35] and Mercury which are higher (so he claims) and, for this reason, larger too than the sphere of Venus,[36] return in position at the same speed as one another and as the sphere of Venus. For, since the smaller [spheres] are no longer hindered to the same degree by the outermost revolution because of their distance, they move at the same speed as [spheres] larger than they are.

But the claim that the sphere of Mercury is above the [sphere] of Venus is either a scribal error which has Mercury instead of the Sun or it is stated according to the opinion of the ancients, an opinion according to which in fact Plato constructs the [celestial] spheres in his *Republic*[37] when he says that sixth from above is the [whorl] of Venus which is second in whiteness after Jupiter[38] and seventh is the Sun and eighth, the Moon—so that Mercury is placed above Venus. But observations in which the star of Mercury is reported running beneath the [star] of Venus make clear in fact that Mercury is found *below* Venus. This fact is proven as well from the account of the distance of their apogees and perigees, since the greatest distance of

[32]Cf. *De caelo* 1.4 for Aristotle's argument that no circular motion has an opposite.

[33]474.2–3 ἥ τε τοῦ μεγέθους πρὸς τὸ τάχος ἀναλογία. This is not the happiest of formulations, but it is still consistent with the idea that a ratio can obtain only between like magnitudes.

[34]474.6 τοῦ πλανωμένου τὴν ἰδιότητα. The definite article is used generically here.

One might be tempted to add that the degree to which a planet makes this unique nature evident varies as its distance from the sphere of the fixed stars.

[35]474.9 τοῦ Ἄρεος. There is an error here: the sidereal period of Mars is not the same as that of Venus and Mercury as Simplicius well knows [cf. Heiberg 1894, 495.23–29]. Perhaps, we should read 'of the Sun' (τοῦ 'Ηλίου) rather than 'of Mars'.

[36]474.10 τῆς Ἀφροδισιακῆς.

[37]Cf. *Resp.* 616e8–617a4.

[38]Note that Venus is the second *brightest* object in the night sky, the first being the Moon.

Venus is proven somehow to be the same as the distance of the Sun[39] (so that Venus is close to the Sun), and the greatest [distance] of Mercury is [proven] somehow [to be] near the least [distance] of Venus, and the greatest [distance] of the Moon [to be] near the least [distance] of Mercury. Certainly, these facts are proven in Ptolemy's *Syntaxis*, if the account of the eccentricity of the planets is transformed into an account of their [eccentricity][40] from the center of the Earth.[41] But, as has

[39] 474.23. Note that, whereas Ptolemy assigns greatest and least distances to the Sun in his *Hyp. plan.* [cf. Goldstein 1967, 7 col. 1; Morelon 1993, 64–66], he indicates only that it has one distance at *Alm.* 5.15, 1210 Earth radii. That is, he does not assert, for instance, that this distance of 1210 Earth radii is a mean distance. So it would seem that Simplicius is indeed drawing on the *Almagest* here, as he says. But see note 41 below.

[40] 474.28: *scil.* ἐκκεντρότητος. Simplicius here calls each planet's distance from the center of the Earth an eccentricity, and so indicates a less technical usage in which the eccentricity of two circles simply amounts to the distance between their centers: cf., e.g., Geminus, *Intro. ast.* 1.31–41; Cleomedes, *Cael.* 1. 4.49–71, 2.5.139–141; Theon, *Exp.* 3.49 [Hiller 1878, 201.7–13]. For the meaning of 'eccentricity' in the *Almagest*, see note 41 below.

[41] In Ptolemy's *Almagest* (= *Syntaxis mathematica*), the 'distances' of the apogees and perigees of the planetary bodies are given in angular measure along the ecliptic from some reference point. Thus, for example, the Sun is said to have its apogee at 24;30°in advance of the summer solstice in *Alm.* 3.4. Moreover, each planetary eccentricity is reckoned as a ratio of the distance between the center of the planetary eccentric circle and the center of the zodiacal circle (where the observer is) to the radius of the eccentric circle, where this radius is assigned a value of 60 units [cf. Heiberg 1898–1903, 1.233.18–22]. So plainly, what Simplicius is ascribing here to the *Almagest* is not found in that treatise—barring the idea that the distance from the Earth to the Sun is constant [see note 39 above]. In fact, it is in Ptolemy's *Hypotheses planetarum*, specifically, book 1, that these eccentricities are computed according to a nesting hypothesis to yield maximum (M) and minimum (m) distances in Earth radii of each planet from the Earth, where $(M+m)/2-m$ is what Simplicius calls an eccentricity [see note 40 above]. So, I repeat, it is odd that Simplicius does not refer to the *Hyp. plan.* here to make his point, especially given that he does allude later to book 2 of this treatise in his remarks on *De caelo* 2.12 [cf. Heiberg 1894, 506.16–22]. Perhaps Simplicius did not have the full text of the *Hyp. plan.* before him but had access only to parts of it and some idea of its general program.

In this respect, Simplicius would be much in the same position as Proclus (410–485), an important predecessor of Simplicius in the Academy at Athens and a source whom Simplicius cites 39 times by name in his commentaries. Proclus asserts in his commentary on Plato's *Timaeus* that Ptolemy did not really concern himself with planetary distances in the *Hyp. plan.* [Diehl 1903–1906, 3.62.22–24]. Still Proclus was aware of the mathematical details of the nesting of Mercury and Venus between the Moon, and Sun as presented in Ptolemy's *Hyp. plan.* And he does indicate [Diehl 1903–1906, 3.62.24–63.22] the *sort* of reasoning on the basis of what is proven in the *Almagest* that *might* have led Ptolemy to this nesting hypothesis. Nevertheless, in his *Hypotyp.* 7.19–23, Proclus been said,[42] since this is either a scribal error or a claim made according to a more ancient construction of the [celestial] spheres, it does not need much argument.

Alexander also states another cause of the fact that the [planets] closer to the fixed [sphere] return in position more slowly, namely, that the upper spheres are larger. Indeed, it is clear that containing [spheres] are larger than contained [spheres]. But, unless the ratios of the distance [from the Earth] to there, that is, [unless the ratios] 475.1
of the sizes [of the spheres] are known, it is not possible to say that their speeds are proportional to their sizes. For, inasmuch as the sphere of Saturn returns in position in 30 years, that is, in 360 months, let us suppose rather roughly that the Moon [returns in position] in one month:[43] if in fact the size of the Saturnian sphere were

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ascribes the nesting hypothesis to some unnamed astronomers rather than to Ptolemy. It would appear, then, that Proclus too lacked a complete text of Ptolemy's *Hyp. plan.* [cf. Neugebauer 1975, 918–919], though he did apparently know that it came in more than one book [cf. Kroll 1899–1901, 2.230.14–15].

So, why does Simplicius ascribe the placement of the models for Venus and Mercury between the Sun and the Moon to Ptolemy and the *Almagest*? I suggest that Simplicius was aware that

> an incredible numerical accident seemed to prove that the models for Mercury and Venus, as constructed in the *Almagest*, could be fitted into the space between moon and sun such that the maximum geocentric distance for the moon coincided with the minimum distance of Mercury, whose maximum distance would determine the minimum distance of Venus, which at it maximum distance would reach the solar orbit. [Neugebauer 1975, 917]

and this is what moved him to speak of Ptolemy and the *Almagest* in this context. Moreover, I would suggest that, on this point at least, Proclus may have been his source. As I have already indicated, this information is offered by Proclus in his commentary on the *Timaeus*, and Proclus introduces the extremal values of the distances of the Moon, Mercury, Venus, and Sun (that are found coincidentally in the *Hyp. plan.*) as results that may be derived from what is proven in the *Almagest* [Diehl 1903–1906, 3.62.24–63.20]. In short, Simplicius, who does draw on Proclus' *In Plat. Tim.* later in his own commentary on the *De caelo* [cf., e.g., Heiberg 1894 662.32–663.6, 663.27–664.4], may in this passage just be repeating Proclus' remarks in a compressed way. (This would not preclude Simplicius' having access to (parts of) book 2 of the *Hyp. plan.* either directly or through other sources.)

[42] Cf. 474.14–16.

[43] Simplicius takes Alexander to be proposing that the speeds of the planetary motions in longitude are proportional to the sizes of the planetary spheres. In attacking this on the ground that it requires one to know the planetary distances from the Earth, Simplicius considers a counterfactual claim which indicates that he also takes Alexander to suppose that all the planets revolve with the same linear speed—that is, they define arcs of equal lengths in equal times—and, thus, that their angular speeds are inversely proportional to their distances measured from the Earth. Cf. Vitruvius,

greater than 360 times the [size] of the lunar sphere, it would be possible to declare that the sphere of Saturn moves faster than the lunar [sphere], since what moves a greater distance in an equal time must move faster, especially in case of [bodies] that move smoothly.[44]

Not only Aristotle but also Plato thinks that what moves on smaller circles moves faster than what moves on larger circles.[45] At any rate, he says in his *Timaeus*:[46]

De arch. 9.1.14–15. For, given that 30 years is a crude but standard value for the length of Saturn's sidereal period [cf., e.g., Geminus, *Intro. ast.* 1.24; Pliny, *Hist. nat.* 2.32; Cleomedes, *Cael.* 1.2.22–24] and 30 days another common value for the length of the month, one might certainly think that the values obtain holds because both bodies move at the same linear speed or, equivalently because Saturn is 30 times as far from the Earth as the Moon. And this certainly makes sense of Simplicius' suggestion that Saturn would move at a faster linear speed than the Moon's if its geocentric distance were more than 30 times the geocentric distance of the Moon. Indeed it is hard to construe this counterfactual claim and Simplicius' polemic otherwise.

Kepler in his *Mysterium cosmographicum* [Duncan and Aiton 1981, 197] cites *De caelo* 2.10 for the view that the speeds of the planets are proportional to their distances. To explain this he imputes to Aristotle the thesis that the movers of the planets impart an equal (linear) motion to each, that is, 'each particle of Saturn is indeed as fast-moving as the lowest sphere of the Moon'. But, if the planets share the same linear speed, as Kepler suggests, it follows that they trace out equal arcs in equal times and, thus, that their angular speeds vary inversely with their distance from the Earth. The problem with this is twofold. First, if the angular speeds of the planets vary inversely with their distance from Earth, then these angular speeds do *not* vary directly with the distances of the planets from the fixed sphere. Hence, it is no longer true that the planet's motion, that is, the time it takes for it to go through its circuit, is proportional to its distance from the fixed sphere, as Aristotle plainly wishes to have it [see p. 27n1, above]. It is important to realize that in citing Aristotle's thesis that the motions of the planets vary as their distances, Kepler omits to define the point from which the distances are reckoned. Second, as 291a6–10 make clear, for Aristotle, the proportionality of the periods and distances is to be explained by reference to the influence of the motion of the sphere of the fixed stars, and there would thus seem to be little room for this in Kepler's account. Indeed, Kepler states that such influence is alien to his scheme. In sum, we should not suppose that the planets are to have the same linear speed in *De caelo* 2.10.

[44]That is, granted that the sidereal period of Saturn is 360 months, if its sphere were more than 360 times the size of the lunar sphere, a point on the equator of the sphere of Saturn would travel a larger arc in a month than a point on the equator of the sphere of the Moon, which would mean that the sphere of Saturn revolves faster.

[45]Given what follows, the speed now in question would seem to be simply the time it takes a planet to complete a full revolution.

[46] *Tim.* 38e6–39a3.

> [The beings needed to produce time together] are sent around[47] along the oblique motion of the Different, which goes round through the motion of the Same and is dominated [by it][48]—one group of them[49] moving on a greater [circle], the other on a smaller [circle]; those on a smaller [circle] faster, those on a larger [circle] more slowly.

And in the *Republic*,[50] when he speaks of the ordering of the [planets] and puts the fixed [sphere] first, the Moon eighth and the others in between, he adds:

> the eighth [goes] the fastest of these; the seventh, sixth, and fifth are together with one another, second;[51] the fourth goes third in motion;[52] while the third is fourth and the second, fifth.

But Plato may be able to say that the lower [planets] move faster by paying attention to the time interval of return in position alone—because they do return in position in a shorter [time interval]—but not in fact to the ratio of the size [of the planetary sphere]. For, if, as has been said,[53] the ratio of the size [of the sphere] exceeds the ratio of the time interval of its motion, it is possible for what returns in position in a shorter time interval to be slower.

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[47] 475.14 περιίεται. The received text has περιῄειν ('they kept revolving'): cf. Burnet 1902 *ad Tim.* 39a2.

[48] 475.12 διὰ τῆς τοῦ αὐτοῦ φορᾶς ἰούσης τε καὶ κρατουμένης. This is the reading offered by the best manuscripts of Simplicius' commentary and it is virtually the same as that found in the best manuscripts of Plato's *Timaeus*. As Taylor [1928, 202–203: *ad* 39a1] rightly points out, however, it is a very problematic reading: at 36c4d1, Timaeus asserts that undivided motion of the Same has been given dominance or power (κράτος) over the motion of the Different, but now, in the very process by which this power is exerted, the motion of the Same is putatively dominated. On the basis of the Latin translations of this passage by Cicero and Calcidius, Taylor suggests that the original text was probably διὰ τῆς τοῦ αὐτοῦ φορᾶς ἰόντα τε καὶ κρατουμένην (*scil.* φοράν at *Tim.* 38e6. i.e., 475.11). The idea is that the genitives ἰούσης and κρατουμένης have been obtained as the result of a false assimilation of the earlier accusatives, ἰόντα and κρατουμένην, to the case of φορᾶς. This is the reading found in Karsten's edition of Simplicius' commentary (Heiberg's c).

[49] 475.12 [*Tim.* 39a2] τὸ μὲν... τὸ δὲ: the definite articles are generic, which facilitates the transition to the plurals, τὰ... τὰ, in 475.13 [*Tim.* 39a3]. As Taylor [1928, 203–204: *ad* 39a2] observes, the construction here is complicated and artificial.

[50] Cf. *Resp.* 617a7–b3.

[51] 475.16 δεύτερον: Karsten's edition (Heiberg's c) has δευτέρους as is found in the Plato mss.

[52] 475.17–18: Plato [*Resp.* 617b1–2] has τρίτον δὲ φορᾷ ἰέναι, ὡς σφίσι φαίνεσθαι, ἐπανακυκλούμενον τὸν τέταρτον ('Third in motion, as it appears to them, goes the fourth in circling round back [to itself]'). Cf. Bowen 2001, 814–816.

[53] Cf. 475.2–8.

Yet Aristotle seems to find the solution of the problem[54] in this way, namely, on the assumption that the motion of what is nearer the Earth is *by itself* faster. For, if being dominated and resisted by the fixed [sphere] hinders motion itself and makes it slower, it is clear that the motion of [a planet] nearer the Earth is faster intrinsically and not because of its [faster] return in position. [That is, it is clear] unless one should really say that the predominance of the fixed [sphere] does not make the larger revolution (which is as a matter of fact faster and can, in so far as it is within its power, return in position together with the smaller [revolution])[55] *appear* so much faster [than the smaller revolution], and that Aristotle would be the one who gives the explanation for this—not of the fact that the [spheres] close to the fixed [sphere] are slower without qualification but of the fact that they *appear* slower than they are [by nature].[56] For, though the [larger spheres] are going, so far as it is within their power, to return together with the smaller spheres—if it could happen—[these larger spheres] fall short by the amount [they do] of returning in position together [with the smaller ones] because of the predominance of the fixed [sphere]. Certainly, in this way too the argument that larger [bodies] perform their natural motion faster and by the amount that they are larger remains unshaken. In fact, it is not at all illogical that a particular form have a capacity[57] such that, while it is a specific thing because of itself, it becomes such and such because of the predominance of what is stronger, just as it has limited capacity because of itself, but exists and moves without limit because of the unmoved cause.

Those who say by way of assumption that all the spheres perform the same motion from the east so that day by day the Saturnian sphere returns within a short distance of its position with the fixed [sphere], and the [sphere] of Jupiter within a greater distance and so forth in this way,[58] escape many other problems, since the motion will in fact have the speeds proportional to the sizes and since things made of the same substance will make the same motion. But this sort of hypothesis

[54] Cf. 471.14–28.

[55] Here Simplicius introduces the assumption that all the planets intrinsically share the same angular speed or period in their motion eastward.

[56] Cf. Euclid, *Opt.* dem. 54 for argument that, of bodies moving at the same linear speed, the one farther from the observer will appear to move more slowly: cf. Heiberg 1895, 240.14–22.

[57] 476.7 ἐπιτηδειότητος ('capacity'): for discussion of this non-Aristotelian piece of jargon as it used by commentators such as Alexander and Simplicius, see Todd 1972.

[58] In effect, they suppose that the planets have only one real motion which goes from east to west, and that their motion eastward is only an apparent motion because we (mistakenly) see their daily falling behind the fixed sphere as an independent motion to the east. Cf. Theon, *Exp.* 3.18 [Hiller 1878, 147.14–19].

has been proven impossible.[59] The reason is that the revolution of any wandering [star][60] must be along a circle and this [circle] must always be the same if its motion has been ordained so that it is in fact knowable.[61] So, will they state that this circle on which they say that each of the wandering [stars] makes its motion from east to west is one of the parallel [circles] or a [circle] oblique to them?[62] Certainly, if it were [one] of the parallel [circles], [the wandering stars] would not have to come farther south or farther north, nor would they have to rise and set at different positions on the horizon.[63] But if [they say] an oblique [circle], each of the wandering [stars] would have to appear during each day farther south or farther north because they all go round the oblique circle, as they say, in accordance with each revolution of the universe except for the degrees which they appear leaving behind.[64] Both these [alternatives] are contrary to the clear [facts].

It is worth knowing that on every hypothesis the problem raised about [planetary] stars that keep pace [with one another][65]—how the contained and the contained

[59]Cf., e.g., Geminus, *Intro. ast.* 12.14–27 who discusses this account of planetary motion and dismisses it.

It is not clear just who these thinkers were, though speculation both ancient and modern is plentiful [see Aujac 1975, 146] but worthless nevertheless, since there is no way to test or confirm it. The most we know is that this account of planetary motion was propounded no later than the first century BC, the period when Geminus was active. It certainly belongs to a time when the motions of the planets were not observed carefully against the background of the fixed stars, that is, when there was no awareness of the planetary stations and retrogradations.

[60]476.17 τοῦ πλανωμένου: the article is generic, as αὐτῶν at 476.18 shows.

[61]476.18 εἴπερ τεταγμένη ἔσται ἡ κίνησις. εἴπερ often indicates a condition that that the speaker views as in agreement with the facts and so may here be rendered by 'since' as well: see Smyth 1971, §2246.

[62]476.20–21. The question is whether each planet makes its westward motion on a circle that is parallel to a great circle on the celestial sphere or on a great circle that is oblique to these parallel circles. The alternatives are not as clear as one should like; but given the criticism that follows, it would seem that Simplicius is asking whether the planets are to move westward on circles parallel to the celestial equator (just as the fixed stars) or whether they are to do this along the zodiacal circle [see note 63, below].

[63]Thus, the planets would behave like fixed stars in that they would be unchanging in their relation to the celestial pole and would rise and set at the same point on the horizon. Cf. Geminus, *Intro. ast.* 12.19-21. Note that, if the circles in question were parallel to the zodiacal circle, the planets would rise and set at different points on the horizon.

[64]Thus, the planets would all be like the Sun and Moon and there would be no stations and retrogradations. Cf. Geminus, *Intro. ast.* 12.22–24.

[65]476.28 περὶ τῶν ἰσοδρόμων ἀστέρων. Mercury, Venus, and the Sun are said to keep pace with one another because they have same sidereal period: cf. 474.9–12. Plato [*Tim.* 38d2–4] describes the

spheres, or to say the same thing, how the larger and smaller [spheres] return in position in an equal time interval—still remains a problem. For, whether one says by way of assumption that both the fixed [sphere] and the wandering [spheres] move in the same direction[66] or that the spheres which come close to the fixed [sphere] move more slowly because they are dominated by it, in neither way is the proportion
477.1 of the sizes to the speeds preserved in the case of the [spheres] that keep pace [with one another], either of those that are in themselves closer to the fixed sphere or of those smaller ones that move faster.

In Arist. de caelo 2.11

291b11–17

> *One may suppose with especially good reason that the shape of each of the heavenly bodies is spherical. For, since it has been proven that they do not by nature move of their own accord,*[1] *and since nature does nothing without reason or in vain, it is clear that [nature] has in fact given to these immovable objects a shape of the sort that is least movable. But the sphere is least movable because it has no organ for motion. Consequently, it is clear that [the heavenly bodies] must be spherical in bulk.*

477.5 He has already said in fact that the [fixed and wandering] stars are spherical because they are made of the same substance as the heavenly body,[2] and he has proven through their being spherical that they are immovable with regard to locomotion. But he was taking their being spherical more as a starting-point, which is why he has also said the following: '*Further, since*[3] *the heavenly bodies are spherical, just as the others say and it is agreed by us*'.[4] And using the connective particle 'since' and not simply a hypothetical,[5] he reasonably introduced the rather obvious justification [for

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circuits of the Mercury and Venus as keeping pace with the Sun in speed; and he plainly means only that they have the same period as the Sun, since he adds [*Tim.* 38d4–6] that Mercury and Venus overtake and are overtaken by the Sun: see Bowen 2001, 815–816.

[66] Literally, 'from the same [parts]'.

[1] See *De caelo* 2.8 for Aristotle's argument that the no star (fixed or wandering) moves itself, rather, that each is moved by the heavens as a whole or, more exactly, by a circle (*scil.* sphere) that carries it around. Granted the argument is ostensibly made only in reference to the daily rotation westward of the heavens, but it is easily extended to account for planetary motion eastwards and was so understood.

[2] 477.6 τῷ οὐρανίῳ σώματι: *scil.* aether, which is shown to be spherical in *De caelo* 2.4.

[3] 477.8 ἐπεὶ: the better manuscripts of the *De caelo* have ἐπειδή: cf. Allan 1955, *ad* 290a7.

[4] *De caelo* 290a7–8.

[5] 477.9 ὑποθετικῷ ἁπλῶς: *scil.* εἰ ('if').

this] through the phrase,[6] '*since*[7] *they do generate [them] from that body at least*'. Thus, while he there records that the heavenly bodies are spherical on account of their motion, he now proves directly that they are spherical by using two arguments of which the second is double.

First is the [argument] from their not performing motion on their own accord. (He says this [motion] on their own accord is one that involves change from place to place: walking is of this sort.) Now, taking once more as an axiom the fact that nature does nothing without reason and holding as something proved in advance the fact that the heavenly bodies are immovable with regard to locomotion on their own accord, he reasons in effect as follows:

> The heavenly bodies are immovable with regard to locomotion on their own accord. Bodies of this sort have no organ for this sort of motion because nature does nothing without reason. But bodies that have no organ for [loco]motion are spherical because they have no protuberance. Consequently, it is clear that the heavenly bodies must be spherical in bulk, that is, in body.[8]

But, if he proved earlier that [spherical bodies] do not move by changing place because they are spherical, by considering the motion that is proper to spherical [bodies] on the basis of a division,[9] and if he now proves that they are spherical from their not moving [from place to place], how is the proof not circular? Now, they say in reply that he neither proved their not moving [by changing place] through their spherical [shape] alone nor their spherical [shape] through their not moving [from place to place] alone, but that both the former [conclusion] and the latter are proven through many arguments. And for this reason, says Alexander, the proof is not circular. But how does the fact that the same conclusion is drawn from other arguments as well make *this* demonstration not circular? Certainly, while the fact that [this conclusion] is demonstrated not only through these circular [arguments] but also through other [arguments] may be a sign that, and a reason why, [the conclusion] is not overturned, how can this be a sign that, or reason why, these

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[6] *De caelo* 290a8–9.

[7] 477.11 εἴπερ: cf. p. 41n61, above. The received text of the *De caelo* has εἰπεῖν at 290a8 which goes with the preceding phrase quoted immediately above (καὶ ἡμῖν ὁμολογούμενον εἰπεῖν), thus making γεννῶσιν a dative plural participle that modifies ἡμῖν rather than a third person plural present indicative verb. This reading is supported by 289a13–19.

[8] 477.23–24 ὥστε δῆλον ὅτι σφαιροειδῆ ἂν εἴη τὰ ἄστρα τὸν ὄγκον. It is not clear that this sentence should count as a quotation of *De caelo* 291b16–17 or as a close paraphrase, since it supplies τὰ ἄστρα which is only understood in Aristotle's text.

[9] 477.25 ἐκ διαιρέσεως ('on the basis of a division'). At *De caelo* 290a7–12, Aristotle proposes that a spherical body can move on its own accord in only two ways—by rolling (κύλισις) or by rotation (δίνησις).

proofs are not circular? Perhaps, then, Aristotle took spherical [shape] and not having an organ for locomotion (which necessarily implies not moving by changing place) as convertible, and reasonably demonstrated the one from the other, just as someone might infer having milk from having given birth and having given birth from having milk or that it is man from being a mortal rational animal and the definition from man.[10] For proofs that are circular in this way are not to be cast aside.

It is necessary to understand as well from these [remarks] what kind of motion Aristotle denies the heavenly bodies, namely, that [he denies them] the motion that is not proper to spherical shapes, that is, locomotion by means of organs. For, with regard to this sort of motion, he says that the spherical shape is least movable and adds the cause, '*because [it] has no organ for motion*',[11] inasmuch as he said that motion *in* itself is most proper to spherical [bodies], not only to the heavens but also to the heavenly bodies, when he wrote the following:

> *This is in fact why the heavens as a whole and each of the heavenly bodies seem with good reason to be spherical. For the sphere is the most useful of shapes for motion in itself,*[12] *since it can move very fast in this way and above all occupy the same place. But it is least useful for motion forwards, since it is least like [bodies] that move*[13] *of their own accord because it has nothing hanging loose or projecting as a rectilinear [shape does].*[14]

In fact, what is said here[15] also agrees with these words in that Aristotle says that the heavenly bodies make this apparent change in position not on their own accord, and clearly presents their [motion] in themselves as a proper [motion] of spherical shape. This is why he also says both things about spherical shape, namely, both that it is least movable with regard to locomotion on its own accord and that the sphere is the most useful of shapes for motion in itself.

291b17–23

Further, one and all [the heavenly bodies] are alike,[16] *and the Moon shows*

[10]Man is defined as a mortal rational animal. This definition, which does not actually appear in Aristotle's writings, is a stock example in the works of Alexander of Aphrodisias for instance. Cf. Todd 1976.

[11]*De caelo* 291b16.

[12]478.22 ἐν ἑαυτῷ. The better manuscripts of the *De caelo* have ἐν τῷ αὐτῷ (in the same [place]) at 290b2: cf. Allan 1955 *ad* 290b2.

[13]478.25 κινουμένοις. The received text of the *De caelo* has κινητικοῖς ('can move').

[14]*De caelo* 290a35–b7.

[15]*scil.* in *De caelo* 2.11.

[16]479.1: Simplicius has 'if (εἰ) one and all are alike' in his lemma: thus, as he would have it, Aristotle writes

> *through visual [evidence] that it is spherical: certainly, [if the Moon were not spherical,] it would not as it waxes and wanes become for the most part crescent-shaped or gibbous and halved (dicovtomo”) only once. And, again, [it is shown] through astronomical [considerations] that the eclipses of the Sun would not be crescent-shaped. Consequently, since one [heavenly body] is like this, it is clear that the others too must be spherical.*

As for the second argument, this one is probative of the spherical [shape] of the heavenly bodies in that it applies the axiom which says that each and every heavenly body is alike in shape since they are all in fact [made] of the same substance which is simple.[17] So, if the Moon is proven spherical from its observed illuminations, it is clear '*that the others too must be spherical*'.[18] Certainly, if [the Moon] were not spherical but, say, drum-shaped or lentil-shaped,[19] its illuminations would not, he says, become such that as it waxes and wanes it appears for the most part crescent-shaped or gibbous and *dichotomos*[20] only once. Now, if he were calling the Full Moon *dichotomos*, as Aratus called it *dichomēnos*[21] because of its dividing the month in two,[22] the rest [of what he says][23] would be in accord with the fact that [the Moon] often appears crescent-shaped,[24] since it is indeed [crescent-shaped] when it waxes 479.3

> Further, [the Earth is spherical] if one and all are like, and the Moon shows through visual [evidence] that it is spherical. Certainly, [if the Moon were not spherical]...

[17] *scil.* aether: cf. *De caelo* 1.2 where it is argued that the heavenly bodies are made of aether.

[18] *De caelo* 291b23.

[19] The lentil resembles a circular lens with two convex sides.

[20] 479.11 διχότομον. Usually, this means 'halved', as I have already rendered it above. But, since it is difficult to capture in English the linguistic point Simplicius is making here, I will simply transliterate the Greek in the next few lines and use footnotes to clarify what is at issue.

[21] 479.11 διχόμηνον: 'bisecting the month'. Cf. Aratus, *Phaen.* 78, 737. Kidd [1997, 427–428] remarks that Aratus' διχόμηνα δὲ παντὶ προσώπῳ at *Phaen.* 737 involves a slightly confusing word-play between the half-moon, which is the first-quarter, and the half-month, which is the full-moon'. Simplicius detects the same ambiguity in Aristotle's διχότομος.

[22] The Full Moon is called διχότομος because it divides the month into two halves. Thus, διχότομος is given an *active* sense and 'only once' is taken to mean 'only once during the month'.

[23] viz. that it is διχότομος only once.

[24] 479.12. The text will not do as it stands. Heiberg's conjecture, συνεφώνει καὶ τὸ, introduces an idiom of the form καὶ τὰ ἄλλα καὶ τὸ X meaning that 'X (= the fact that [the Moon] often appears crescent-shaped) particularly' would be in accord. But this leaves open what is being accorded with; and it renders problematic the remark at 479.13–14, 'and it is gibbous under the same conditions'. After all, if the preceding sentence is particularly (and only) about the Moon's appearing crescent-shaped, what is the point of alluding to the Moon's being gibbous?

and when it wanes, and [with the fact that it often appears gibbous, since] it is gibbous under the same conditions. But, inasmuch as a little later he applies the term '*dichotomos*' as it is in fact ordinarily meant when he says

> *That is to say, we have seen the Moon when it was dichotomos as it came under the star of Mars which was in fact hidden*[25] *at its dark side and came out at the bright,*[26] *radiant side*[27]

[these lines] show the meaning of '*dichotomos only once*'[28] nicely. For [the Moon] both as it waxes and as it wanes becomes both crescent-shaped and gibbous for a rather extended interval of time, since the more and the less are in these shapes.[29] [The Moon] will also become *dichotomos* both as it waxes and as it wanes, but not for a specific time interval—the more and the less are not in this shape.[30] Instead, the time interval for [its shape when halved] is momentary, the very thing which '*only once*' makes clear.[31]

There are two possibilities. In reviewing his assessment of the relevant manuscripts [see Heiberg 1894, v], Heiberg affirms that the manuscript which reads συνεφωνεῖτο is primary. So, if one takes this reading as a starting point, the easiest emendation is συνεφωνεῖτο <τῷ>, as proposed to me by R. B. Todd. The assumption here is that the final syllable of συνεφωνεῖτο was originally iterated in the semantically distinct but aurally identical form τῷ which was then subject to easy omission. Still Heiberg also states that this manuscript is primary especially when it is supported by William of Moerbeke's Latin translation. And on this occasion, it turns out that this translation supports the συνεφώνει τὸ found in a number of manuscripts including two that Heiberg thinks very important. So, if one starts with this reading, the easy emendation is συνεφώνει τῷ. Either way, one avoids the difficulties of Heiberg's conjecture and the translation is the same. (For the omission of ἄν in the apodosis of a present contrary-to-fact condition, see Smyth 1920, §2358.b.)

[25] 479.16 ἀποκρυβέντα. The correct reading, which is found in some manuscripts, is ἀποκρυφθέντα: see Allan 1955 *ad* 292a5.

[26] 479.17 φανερόν. The reading found in most manuscripts of the *De caelo* is φανόν: see Allan 1955 *ad* 292a6.

[27] *De caelo* 292a3–6. On Aristotle's report of this occultation, see *ad* 481.8–15 in part 2 of this annotated translation

[28] *De caelo* 291b20–21.

[29] That is, being crescent-shaped or gibbous admits of variations in quantity.

[30] Thus, being halved does not admit of variations in quantity.

[31] The Moon is here called διχότομος when it is divided into halves, that is, when it is at the quarter (either the first or the third). Thus, διχότομος is given its more usual *passive* sense of 'halved' or 'bisected' and 'only once' is construed as 'only for a moment'. It is perhaps misleading to say, as Elders does [1966, 230] that the Moon is διχότομος in this sense for a 'short while': Simplicius is skirting the claim that the Moon is halved for an instant.

These shapes of the [lunar] illuminations are peculiar features of a spherical [body] because, given that a hemisphere [of the Moon] is always illuminated, when the Moon comes beneath the Sun and is at the same degree [of longitude], the part of the Moon toward the Sun is illuminated and the part toward us is dark. But, when the Moon stands apart from the Sun, the hemisphere that is always illuminated leaves behind 480.1
the same amount of the other part[32] as it receives from the [hemisphere] toward us.[33] That is why [the Moon] appears crescent-shaped until the half; and, when half of the upper [hemisphere][34] and half of the [hemisphere] facing us are illuminated, that is, when [the Moon] stands apart from the Sun at a quartile distance,[35] it is seen as halved.[36] From there until diametrical opposition,[37] [the Moon] appears gibbous; but, when it is diametrically opposed [to the Sun], the entire hemisphere facing us is illuminated and the [hemisphere] looking upward is not. And again, as the [Moon] approaches the Sun, it maintains for us a gibbous, a halved, and a crescent-like [shape], and in conjunction a dark [shape].[38] The cause is what I have said: viz. the fact that, since the Moon is spherical, a hemisphere of it is always illuminated.

Consequently, if [the Moon] were in truth drum-shaped or lentil-shaped, it would be the same as it currently is in its conjunctions and Full Moons. But, when it stood apart from the Sun at any distance whatsoever in either direction, [the Moon] would no longer be crescent-shaped or halved or gibbous. Rather, if drum-shaped, the [part] facing us would be illuminated entirely because there is no obstacle to the [Sun's] rays; whereas, if lentil-shaped, since there was a little bulge in the middle, the shape of the illumination would turn out to be different.[39]

[32] That is, the part that was turned to the Sun and illuminated during conjunction.

[33] In other words, the intersection of the hemisphere that is always illuminated and the hemisphere that is facing us is equal to the complement of these same two hemispheres. See Figure 1 (pp. 51–52).

[34] The direction from the Earth along a radius of the celestial sphere to the fixed stars is up. Thus, the upper hemisphere is the complement of the hemisphere that is toward us.

[35] 480.4 τετραγωνικὴν διάστασιν. The notion of a quartile distance apparently derives from astrology and originally pertains to zodiacal signs that are separated by three zodiacal signs or 90°: cf. Geminus, *Intro. ast.* 2.16–26; Ptolemy, *Tetrabib.* 1.13.

[36] That is, bisected or at the (first) quarter.

[37] 480.5 μέχρι τῆς διαμέτρου. This term may have an astrological nuance as well: cf. Geminus, *Intro. ast.* 2.2–6; Ptolemy, *Tetrabib.* 1.13.

[38] See Figure 1 (pp. 51–52). For an even fuller account of the lunar phases along the same lines, see Cleomedes, *Cael.* 2.5 [Bowen and Todd 2004].

[39] See Figures 2 and 3 (pp. 53–54) with the additional comment (p. 49).

Next, he introduces another proof also from astronomy, namely, '*that the eclipses of the Sun would not be crescent-shaped*'[40] as they are now seen [to be] unless the Moon which comes beneath it were spherical. Certainly, it has been proven that, when a sphere is obscured by a sphere, the sections [of the sphere obscured] are of this sort.[41] But never in fact do other rounded [objects], such as drum-shaped and lentil-shaped [bodies], produce sections that are crescent-shaped when they cover [a sphere].[42] Indeed, if it is posited that they move about their own centers, drum-

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[40] *De caelo* 291b21–22.

[41] Cf. *De caelo* 297b23–30, where the shifting boundary line of light and dark observed on the Moon during a lunar eclipse is the evidentiary basis for inferring the shape of the Earth:

> Further, [the shape of the Earth is also known] through perceptual phenomena. For, [if it were not spherical,] eclipses of the Moon would not have the sorts of sections [that we see]. Certainly, as a matter of fact, [the Moon] receives all divisions in its monthly configurations, since it does become straight and convex and concave. And in eclipses it always has the line delimiting [the shadow] convex, so that since [the Moon] is eclipsed because of the interposition of the Earth, the Earth's curvature (which is spherical) must be the cause of the [shadow's] shape.

As Neugebauer [1975, 1093–1094] remarks,

> even if we take it for granted that the shadow of one object on another unknown surface appears as a circle one should remember that there exists an unlimited number of shadow casting and shadow receiving bodies which produce identical shadow limits.

Still, if one assumes for the moment that the Moon is a flat disk, all one needs to reach the desired conclusion is the argument that, since lunar eclipses can occur at any longitude, the Earth must be a uniformly curved *in every direction*, that is, spherical.

[42] This is wrong. As Simplicius has already indicated [480.10–11], there is no appreciable difference in the *effective* shape of a spherical, a drum-shaped, and a lentil-shaped Moon at conjunction and opposition [see Figures 2 and 3, pp. 53–54)]. So, given that the spherical Moon, the drum-shaped Moon, and the lentil-shaped Moon each present a circular disk to the observer during conjunction and opposition, given that solar eclipses occur when the Moon is in conjunction, and given that it is the *edge* of the lunar disk that defines the boundary of light and dark (Simplicius' 'sections') seen during a solar eclipse, then it follows that all three bodies will produce the same boundaries on the same object.

In short, Simplicius has unwittingly indicated at 480.10–11 why it is wrong to argue that the Moon is spherical because it defines a crescent-shaped boundary during a solar eclipse. His error lies supposing that an argument inferring the shape of a body (the Earth) that casts a shadow on another (the Moon) during a lunar eclipse [480.18–19] is relevant to an argument inferring the shape of a body (the Moon) that blocks another (the Sun) during a solar eclipse. It would have been better if had paid attention to his own examples of the drum-shaped and lentil-shaded Moons, and shaped or lentil-shaped [bodies] will no longer produce sections at every position.[43]

Additional Comment on 480.11–15

(Page 47, note 39)

Simplicius' account of the appearances of a drum-shaped or lentil-shaped Moon is compressed. In the first place, it appears that the drum-shaped and lentil-shaped Moons are to be viewed from the top. Thus, the surface to be seen is circular and flat in the case of the drum-shaped Moon, whereas in the case of the lentil-shaped Moon it is circular with the bulge towards the observer. Obviously, it is true that neither the drum-shaped nor the lentil-shaped Moon will be visible at the beginning of the month. And given that the Moon rotates once in a synodic revolution [see p. 49n43, above], it will also be true that at mid-month both will have the same appearance as the Full Moon, that is, the observer will see a circular disk. When the drum-shaped and lentil-shaped Moons are *not* in syzygy, however, the circular surfaces are illuminated obliquely so that they will either be completely invisible [cf. 480.22–23] or visible completely in the case of the drum-shaped Moon, or visible to an extent in the case of the lentil-shaped Moon that is dependent on the height of its bulge.

Simplicius thus makes clear that one can explain the phases of the Moon if it is spherical in shape but not if it is drum-shaped or lentil-shaped. What one still needs, however, and what no one

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if he had assessed the two arguments offered by Aristotle at *De caelo* 219b17–33 as considerations that jointly lend support to the thesis that the Moon is spherical rather than follow him in treating them as independent and conclusive.

[43]Again, this wrong or at least very confused. Simplicius is either forgetting that eclipses occur only when the Moon is in conjunction or opposition to the Sun, or that the drum-shaped and lentil-shaped Moons are oriented with their circular surfaces to the observer so that they are indistinguishable from the Full Moon when they are in opposition. In any case, *any* Moon-sized object placed in conjunction to the Sun will define an observable boundary of light and dark during a solar eclipse.

On the rotation of the Moon, see Plato, *Tim.* 40a8; Cleomedes, *Cael.* 2.4.1–9 (which ascribes this to Berossus). Aristotle [*De caelo* 2.8: cf. esp. 290a7–29], however, denies that the stars (fixed and planetary) either rotate or roll: for him, the Moon always shows the same face to us because it is fixed to a sphere that revolves about the Earth as its center [cf. Leggatt 1995, 240–241].

There is no precedent, so far as I know, for the hypothesis of a drum-shaped or of a lentil-shaped Moon. But, given that the Moon appears fully circular in opposition and that it rotates once in a synodic revolution, there are three basic classes of figure in that the Moon-shapes must have a circular surface that is either concave, flat, or convex. The drum-shaped Moon has a flat circular surface; the lentil-shaped Moon, a surface that is circular and mildly convex. So, if the hypotheses are Simplicius' own, the question is why he passes over the case of the Moon that has a concave circular surface and merely alludes to it in 480.19–21.

in antiquity attempts to provide so far as I am aware, is the further argument that the lunar phases can be explained *only* on the assumption of a spherical Moon. And perhaps this is understandable: after all, a hemispherical-bowl Moon with the convex side towards the Earth will yield exactly the same phases that are ascribed to the spherical Moon. The point is that the familiar lunar phases are not sufficient evidence by themselves to establish that the Moon is spherical.

Certainly, Aristotle does not attempt such an argument. Indeed, at *An. post.* 78b4–11 he writes:

> Again, [consider] how they prove that the Moon is spherical from its increases—for if what increases in this way is spherical, and the Moon increases [in this way], it is clear that [the Moon] is spherical. Accordingly, there is in this way a syllogism of the fact. But if the middle term is put the other way round, [there is a syllogism] of the reason why, since [the Moon] is not spherical because of its increases, but gets increases of this sort because of its being spherical.

Now the syllogism of the fact that the Moon is spherical will succeed if and only if whatever shows such increases is sphere. As for the second syllogism, if we adapt the formulation Aristotle uses in regard to the planets, their not twinkling, and their being near [*An. post.* 78a31–b4], it is given that being a sphere belongs to the Moon and that having such increases belongs to being a sphere; and from this it is deduced that having such increases belongs to the Moon. (In the first syllogism, the middle term is 'having such increases'; in the second, it is 'being spherical'.) Clearly, the syllogism of the reason why the Moon has such increases will succeed under the same condition as the syllogism of the fact that it is spherical; that is, it will succeed if and only if a sphere produces such increases. (For discussion of Aristotle's distinction here between a syllogism of the fact and syllogism of the reason why, see Barnes 1975, 148–150.)

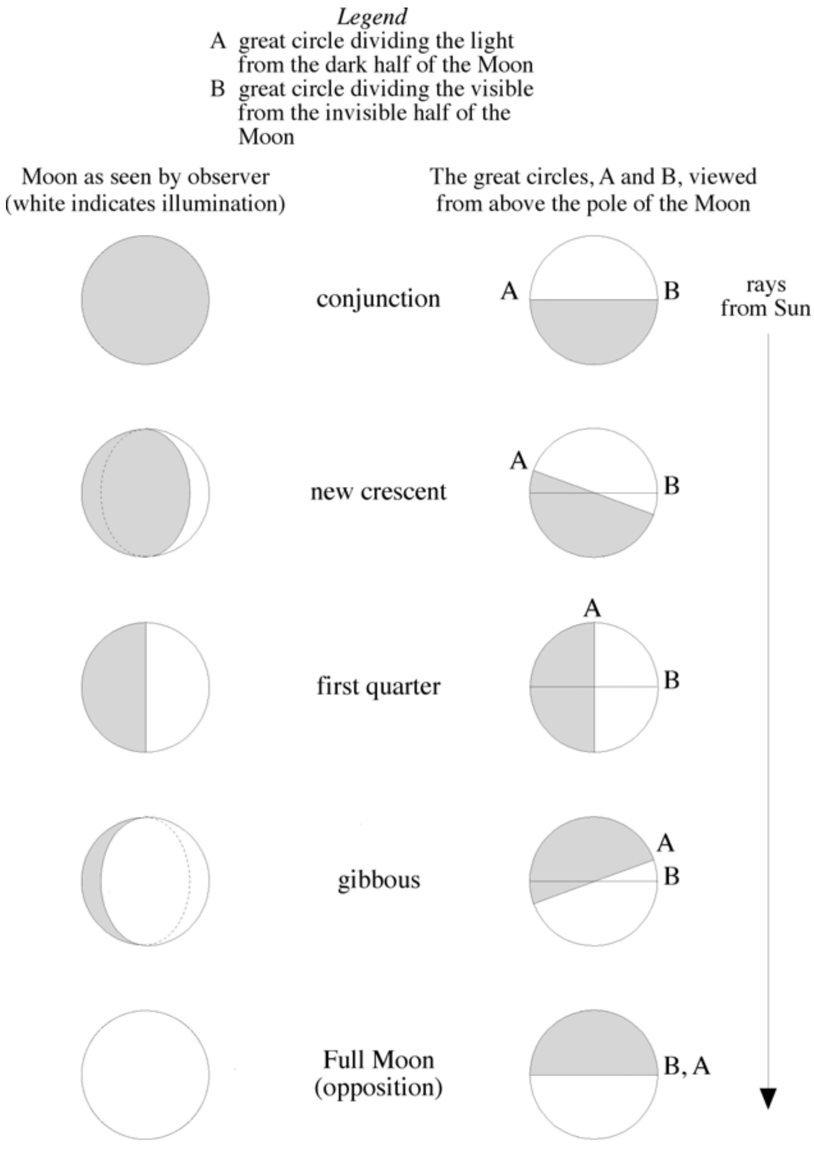

Figure 1(a). The phases of the Moon
from conjunction to Full Moon (479.23–480.7)

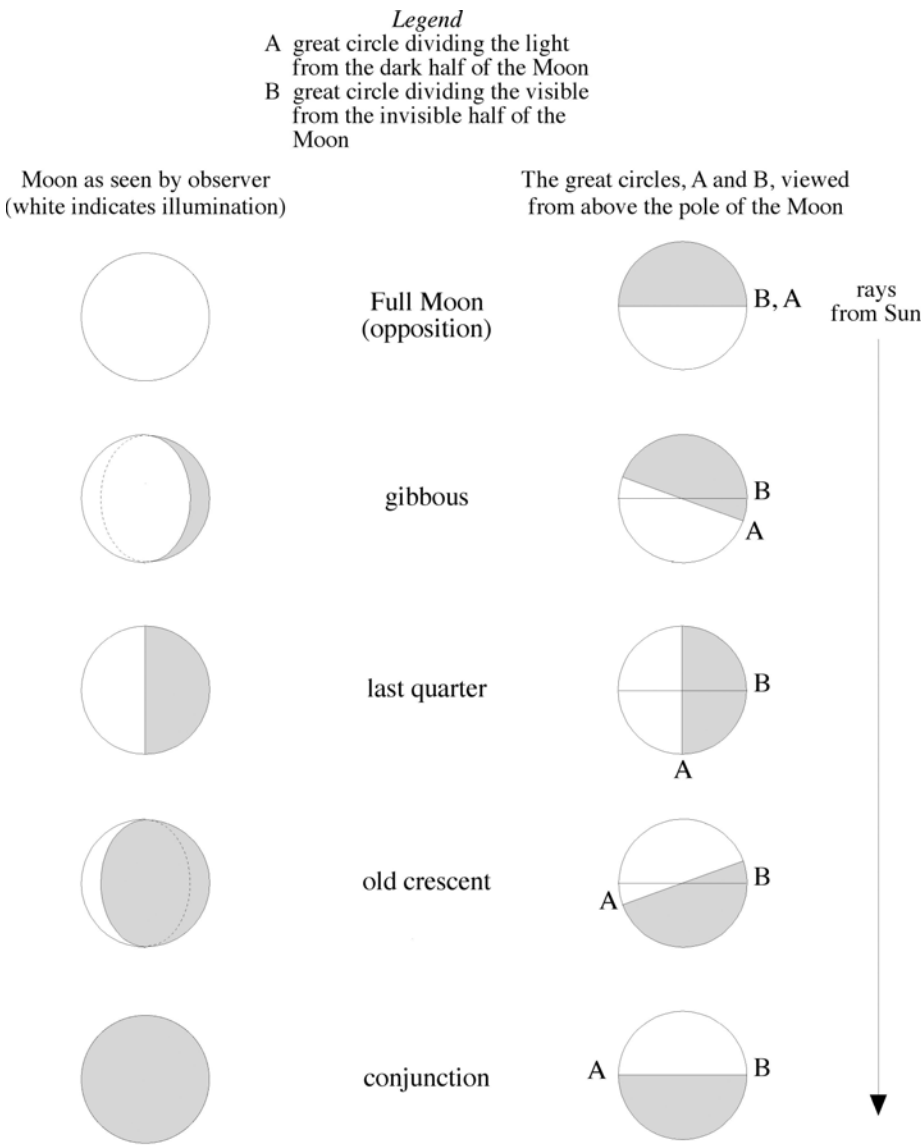

Figure 1(b). The phases of the Moon from Full Moon to conjunction (480.6–8)

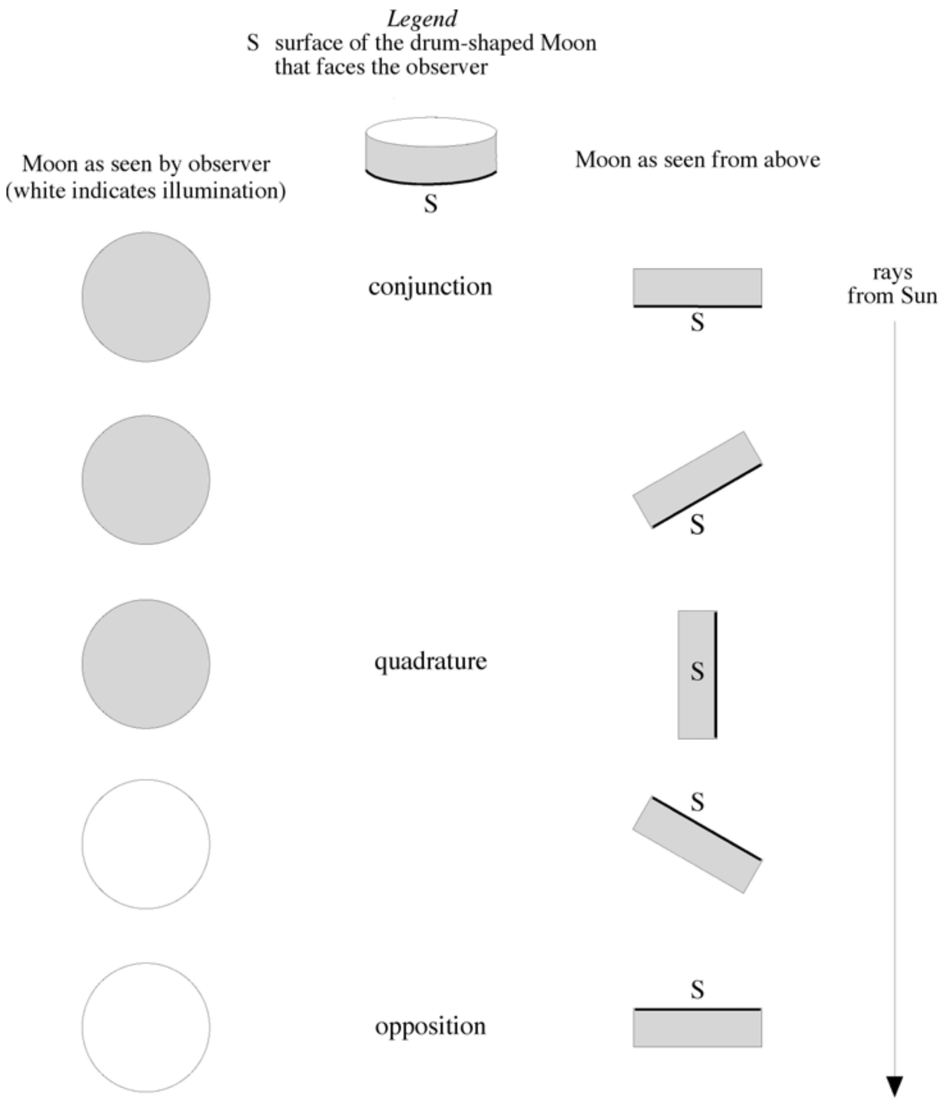

Figure 2. The phases of a drum-shaped Moon from conjunction to opposition (480.10–15)

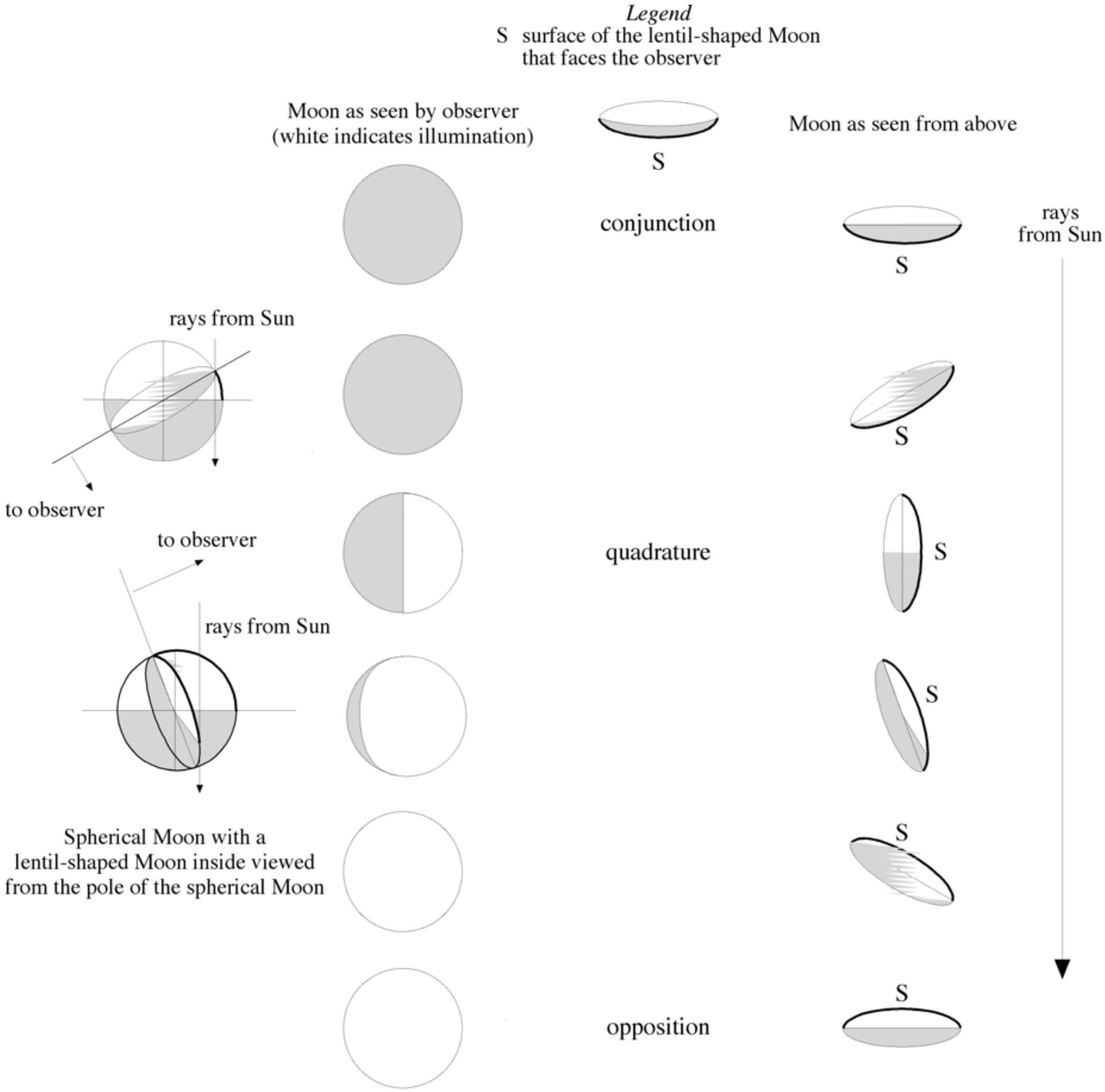

Figure 3. The phases of a lentil-shaped Moon from conjunction to opposition (480.10–15)

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