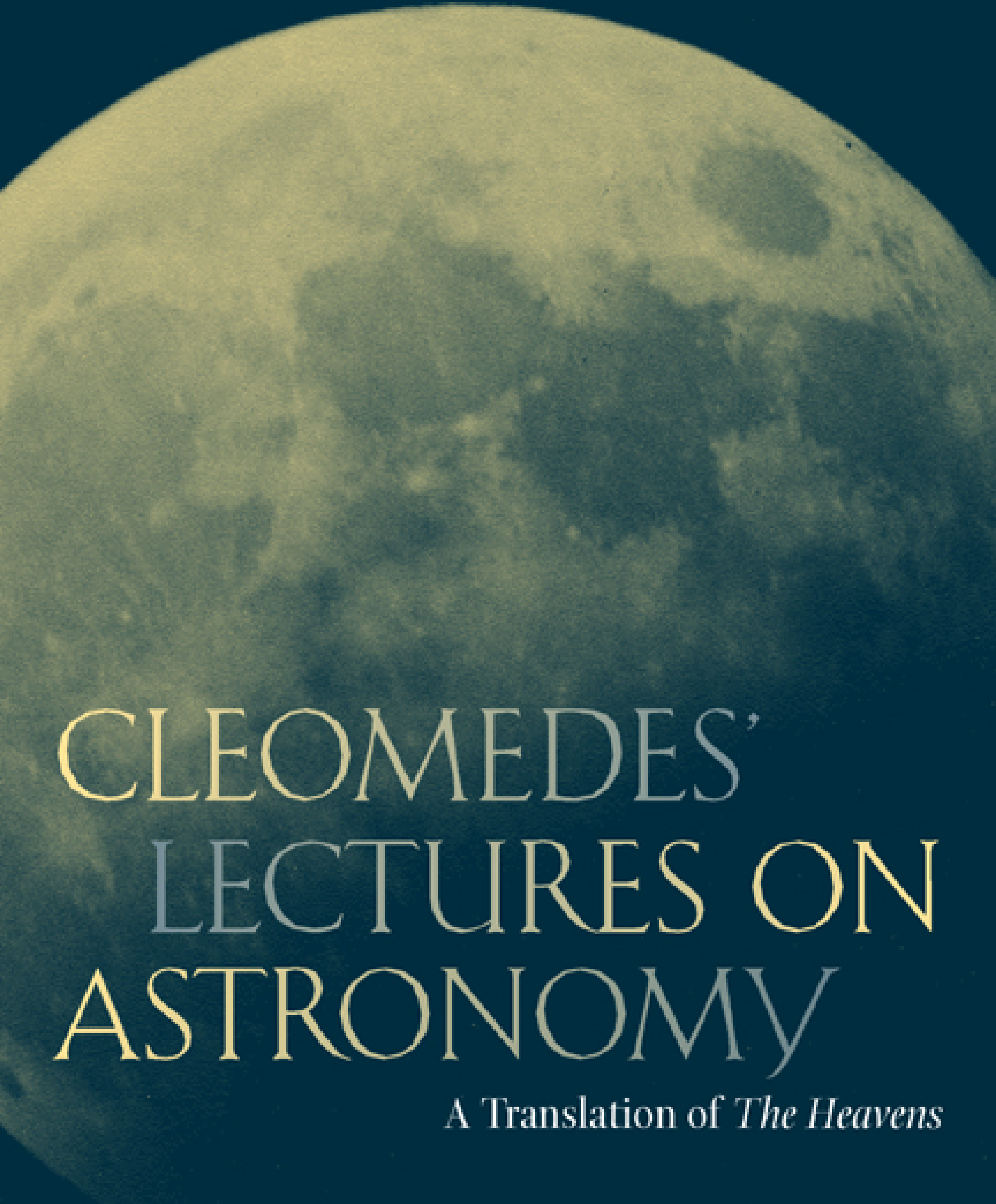
WITH AN INTRODUCTION AND COMMENTARY BY

ALAN C. BOWEN AND *ROBERT B. TODD*



CLEOMEDES' LECTURES ON ASTRONOMY

A Translation of *The Heavens*

The Joan Palevsky Imprint in Classical Literature

In honor of beloved Virgil—

“O degli altri poeti onore e lume . . .”

—Dante, *Inferno*

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Cleomedes' Lectures on Astronomy

HELLENISTIC CULTURE AND SOCIETY

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To David Furley, in gratitude

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PREFACE

The sole surviving treatise by the Stoic Cleomedes may belong chronologically to some time around A.D. 200, but philosophically it is rooted in the Hellenistic period: in the third century B.C. when Stoicism was first established, and in the first century B.C. when that school underwent a renaissance at the hands of Posidonius of Apamea. The treatise itself, a digression on astronomy and some aspects of cosmology, was prepared for pedagogical purposes as part of a larger survey of Stoicism. Had the works of the major Stoics survived, Cleomedes would be an insignificant footnote in the history of this school, marginalized as the minor Platonists of his era are by the survival of the Platonic corpus. But since the foundational works of Stoicism are lost, his treatise takes on a significance that exceeds its merits, but reflects its uniqueness. As the only work of "school" Stoicism from its period to survive intact, it fully warrants the close scrutiny that it receives in the present study.

Cleomedes maintained the doctrines of the early Stoa of Chrysippus, but, as we argue in the Introduction, was also influenced to some degree by Posidonius' important interventions in Stoic philosophy. This major thinker had in particular sought to redefine Stoic physical theory in relation to the science of astronomy, which had made such spectacular advances during his own lifetime. While Cleomedes' own account of astronomy is relatively unsophisticated, his inclusion of this science in an outline of Stoic philosophy at all is testimony to that earlier encounter between science and philosophy, and proof that the Stoa of the first two centuries of the Roman Empire did not, as is often assumed, restrict itself to moral philosophy.

We have anticipated a varied readership for this work, most of whom will not know the ancient languages. We thus offer the first English translation of Cleomedes (the sixth into all languages since the late fifteenth century), and the first based on a critical edition of the Greek text. We have addressed the interests of students of Stoic philosophy (in particular of physical theory and epistemology, the two theoretical components that dominate Cleomedes' treatise), though we have frequently referred them to the rich body of recent scholarship on Stoicism for further discussion of issues that could not be pursued in detail in relation to the Cleomedean evidence.

We have also aimed to reach students of ancient mathematical astronomy, and of the general history of astronomy, though, given the wide range of our intended readership, we have not restructured Cleomedes' text in order to correlate it closely with the technical figures appended to the translation. Cleomedes earned the right to an eponymous lunar crater primarily because he provided the fullest surviving account of the two major ancient attempts to evaluate the circumference of the Earth—projects that retain a perennial interest, and that are summarized in most introductions to astronomy. We make these texts, like the other astronomical material in the treatise, available within a complete presentation of the work from which they are often excerpted, since whatever Cleomedes has to offer contemporary readers is surely best assimilated in the full context in which it was originally composed.

Robert Todd acknowledges the considerable support of the Social Sciences and Humanities Research Council of Canada for his Cleomedean researches over several years. We both thank Henry Mendell and a second reader for the University of California Press for their helpful criticism and suggestions, as well as Stephen Menn for his comments. We

are grateful to Tony Long for his generous support and assistance and indebted to Heinrich von Staden for arranging for us to use the facilities of the Institute for Advanced Study at Princeton in preparing the final version of the manuscript.

Two scholars in particular have in differing ways influenced our study. First, like all students of Posidonius, we are indebted to the monumental labors of Ian Kidd. If we take issue with some of his interpretations, we do so out of the deepest professional respect toward a scholar who has laid such solid foundations for future work. Second, we dedicate our book to David Furley. His writings have long been an inspiration to all students of ancient cosmology, and he has over several decades been to both of us a friend, teacher, and mentor.

Princeton, N.J.
Vancouver, B.C.
February 2003

ABBREVIATIONS

For other abbreviated references to both primary and secondary sources see the Bibliography and the Index Locorum.

Caelestia	R. B. Todd ed., *Cleomedis Caelestia* (*ΜΕΤΕΩΡΑ*) (Teubner: Leipzig, 1990). Since the chapters in this edition have separately numbered lines, references are tripartite, with a *Roman* numeral employed for the two books: e.g., I.5.20. The page numbers of H. Ziegler's earlier edition, *Cleomedis de motu circulari corporum caelestium libri duo* (Leipzig, 1891) are cited in the margins of Todd's edition.

OTHER WORKS

Ach. *Isag.*	Achilles, *Eisagōgē (Introductio in Aratum)*. Ed. E. Maass, *Commentariorum in Aratum Reliquiae* (Berlin, 1898), 25–75. On this author, often mistakenly called "Achilles Tatius," see Mansfeld and Runia (1997) 299–305.

DK	H. Diels and W. Kranz, *Die Fragmente der Vorsokratiker.* 6th ed. (Berlin, 1952).
EK	L. Edelstein and I. G. Kidd eds., *Posidonius: Volume I. The Fragments.* Cambridge Classical Texts and Commentaries 13, 2nd ed. (Cambridge, 1989); with I. G. Kidd, *Posidonius: Volume III. The Translation of the Fragments.* Cambridge Classical Texts and Commentaries 36 (Cambridge, 1999). Posidonius is usually cited from this collection, which includes only fragments that mention him by name.
Gem. *Isag.*	Geminus, *Eisagōgē eis ta phainomena.* Ed. G. Aujac (Paris, 1975).
Goulet	R. Goulet, *Cléomède: Théorie Élémentaire. Texte présenté, traduit et commenté* (Paris, 1980).
Kidd, *Comm.*	I. G. Kidd, *Posidonius: Volume II: The Commentary.* Cambridge Classical Texts and Commentaries 14A and 14B (Cambridge, 1988). The two volumes are paginated continuously and are cited only by page number.
LS	A. A. Long and D. N. Sedley, *The Hellenistic Philosophers.* 2 vols. (Cambridge, 1987).
Ptol. *Alm.*	Ptolemy, *Almagest.* Ed. J. L. Heiberg. 2 vols. (Leipzig, 1898, 1903).
SVF	*Stoicorum Veterum Fragmenta.* Ed. H. von Arnim. 3 vols. (Leipzig, 1903, 1905).
Theiler	W. Theiler ed., *Poseidonios: Die Fragmente. I. Texte; II. Erläuterungen* (Berlin, 1982).
Theon *Expos.*	Theon of Smyrna, *Expositio rerum mathematicarum.* Ed. E. Hiller (Leipzig, 1878).
Usener *Epicur.*	H. Usener ed., *Epicurea* (Leipzig, 1887).

INTRODUCTION

The Heavens (in Latin *Caelestia;* in Greek *Meteōra;* literally "Things in the Heavens")[1] is the only surviving work by the Stoic philosopher Cleomedes. In the absence of any external biographical information on him,[2] his *floruit* has to be inferred from the probable date of his treatise.

1. On the title of the treatise see Goulet 35 n. 1, Todd (1985), *Caelestia* ed. Todd at *Praefatio* xx–xxi and Goulet (1994). The original title, assuming that there was one, is unknown, and we depend entirely on what is preserved in the Greek manuscript tradition. The use of *Meteōra* in the present study reflects a choice made within that tradition (see Todd [1985]) over another title, favored by Goulet 35 (see Todd [1985] 259–260 and Goulet [1994] 438), *Kuklikē Theōria* ("Elementary Theory," with *kuklikos* taken in a pedagogical sense). The title used in editions of the Renaissance, *De motu circulari corporum caelestium*, and retained in H. Ziegler's edition of 1891, is a loose translation of a later synthesis in the Greek manuscript tradition of these two titles: *Kuklikē Theōria Meteōrōn* ("The theory of heavenly bodies as it pertains to motion").

2. For an introductory survey on Cleomedes see Goulet (1994). On the secondary literature see Todd (1992) and (2004). The suggestion at Neugebauer (1941) (= Neugebauer [1975] 960–961) that Cleomedes was from Lysimachia is unduly speculative given that this location is introduced in a passage that is an elaborate reductio ad absurdum of the theory that the Earth is flat; see further I.5 n. 16.

CLEOMEDES' DATE

Clearly this work cannot have been composed earlier than the time of the latest historical figure mentioned in it, Posidonius of Apamea (ca. 135–ca. 51 B.C.).[3] It is also unlikely to have been composed much after A.D. 200 on the general grounds that Cleomedes' polemics against Peripatetics (followers of Aristotle) and Epicureans are typical of debates between the Stoics and their philosophical opponents during the first and second centuries A.D., and are unparalleled after the early third century A.D., as are the pedagogical presentations of Stoic philosophy of which the *Caelestia* is clearly typical.[4] Cleomedes, that is, was a professional teacher who, as internal evidence shows, offered, presumably in the form of oral teaching, accounts of the main topics in Stoic philosophy.[5] Thus, while in the *Caelestia* he deals primarily with elementary astronomy and some aspects of cosmology, he also anticipates and assumes instruction in Stoic physical theory,[6] and cites without explana-

3. This earlier Stoic is named in connection with terrestrial zones (I.4.94, 110, 113, 115), measurements of the Earth and the Sun (I.7.2, 4, 18, 27, 48; II.1.273), refraction (II.1.54), lunar density (II.4.98), and as a general source for II.1 (I.8.162) as well as for "most" of the treatise (II.7.14).

4. On Stoic scholasticism in the first two centuries A.D. see Todd (1989), and in the *Caelestia* see especially I.1.81–111 and II.1 *passim*, and also I.1 n. 31 on parallels in the works of Alexander of Aphrodisias (*fl.* A.D. 200) to the Peripatetic arguments attacked by Cleomedes. As Sharples (1990) 111 notes, Alexander also marked the end of the Peripatetic tradition. See also Algra (2000) 172–173 for the same general view.

5. The origins of this work in oral presentations are suggested by its stereotyped and elementary argumentation, its frequent explications of terminology, and particularly by self-descriptive language such as "introduction" (*eisagōgē*, I.8.60), "lecture courses" (*skholika*, II.2.7; *skholai*, II.7.12; see II.7 n. 7), "instruction" (*didaskalia*, I.1.191), and "learning" (*katamanthanein;* e.g., I.1.114, 189; I.5.8, 30).

6. For an account of the centripetal motion of the elements as the explanation of the stability and sphericity of the cosmos designed for inclusion in a later, but now lost, exposition see I.1.94–95, 173–174, 191–192. For other central

tion doctrines from Stoic metaphysics, epistemology, semantics, and logic.[7] Far from being a "sample of scientific literature in late antiquity,"[8] his treatise is therefore best characterized as the presentation of ancillary material within a larger exposition of Stoicism.[9] A work of this kind is unlikely to have been composed much after A.D. 200.[10]

If there is any other evidence for dating the treatise more precisely between ca. 50 B.C. and, say, ca. A.D. 250, it can be found only in the as-

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doctrines of Stoic physics see I.1.7 and 126–127 (the finitude of the cosmos); I.1.43–49 and 101–103 (the conflagration); I.1.72–73 and 98–99, and I.5.131–132 (pneuma, tension, and *hexis*); and I.1.116–119 (the elements). For the teleological view of nature see I.1.11–16 and 268–269, I.2.2–3, I.4.40–43, I.8.98–99, and II.1.396–399, and for the physical theology that makes planets deities see II.4.129–131, and II.5.5, 75, 92, 100.

7. These include the incorporeals (I.1.141–142 and II.5.100–101), the general definition of body (I.1.66–67), the criterion of truth (I.5.1–6, and II.1.2–5, 140–142), and elements of Stoic logic (I.5.20–22, I.6.2–4 and II.5.92–101; cf. I.1 n. 67). Reports of Stoic arrangements of the parts of their system are so programmatic (see Ierodiakonou [1993]) that we cannot be sure of the order in which Cleomedes introduced the earlier material noted here and in the preceding note. Cf. also II.1 n. 95.

8. Neugebauer (1975) 959.

9. Goulet 15–21 argues that the treatise may have been designed as an introduction to the astronomical poem, the *Phaenomena*, by Aratus (*ca*. 315–240/39 B.C.), and Mansfeld (1994) 197–198 notes the relevance of some ancient scholia on Aratus (cf. II.1 nn. 11, 24 and 31). Yet any such relation to Aratus can only be secondary to the role of the *Caelestia* within a wider exposition of Stoic thought, and is no more significant than Cleomedes' use of Homeric quotations (notably at II.1.470–492; cf. also I.8.60–61 [= II.6.22–23], and II.1.470–471; on this Stoic practice in general see Long [1992]).

10. In addition to the evidence in Todd (1989), the epideictic oratory in the anti-Epicurean polemic (II.1.467–524) links the *Caelestia* with the culture of the "Second Sophistic." Such evidence complements the conclusions of a study of Cleomedes' language and style by Schumacher (1975) which suggests from the evidence gathered of Atticizing an approximate *terminus post quem* of the end of the first century B.C.

tronomical data and theories that Cleomedes presents. One of the observations that he records (I.8.46–56) was used by Otto Neugebauer to assign the work to the fourth century A.D., but, in our view (see I.8 n. 16), the details of the relevant text do not justify such an inference. *Caelestia* I.4.72–89, on the other hand, has been thought to allude to the equation of time. Since this is a subtle concept that Ptolemy (*Alm.* 3.9) was the first to articulate, this passage would justify assigning the *Caelestia* a date no earlier than the middle of the second century A.D. (a *terminus post quem* consistent, as we have seen, with his philosophical culture).[11] However, the Cleomedean text in question just rehearses a point identical to that made by Geminus (first cent. B.C.) in his *Eisagōgē* 6.1–4 regarding the length of the day, with both texts providing an account of the variation in its length that is pre-Ptolemaic.[12] Thus the date of the *Caelestia* cannot be determined by any line of dependence from Ptolemy, and if it is post-Ptolemaic (as cultural considerations would allow; see n. 4 above), then this would mean that Cleomedes was either unaware of or indifferent to the *Almagest*.[13]

11. For this argument see Bowen and Goldstein (1996) 171 n. 27. Ptolemy's *floruit* was ca. A.D. 130–ca. A.D. 170. The *Almagest* itself cannot be dated precisely.

12. Both Geminus and Cleomedes define the day as the interval from one sunrise to the next, and bring into consideration the rising time of the arc which the Sun travels along the zodiacal circle during the course of one revolution of the cosmos. (For a translation of the passage from Geminus see I.4, n. 16.) Ptolemy, by contrast, defines the day as the interval from one meridian crossing by the Sun to the next, and focuses on the time it takes the arc that the Sun travels during a day to cross the meridian circle. In effect, Ptolemy isolates the trigonometric contribution of the Sun's motion to the variation in the length of the day (that is, to the equation of time) by subtracting the effect of latitude. So *Caelestia* 1.4.72–89, far from showing Cleomedes' reliance on Ptolemy, presents an account of the length of the day that Ptolemy clarified and made precise.

13. See Algra (2000) 168 with n. 16 for this general conclusion.

CLEOMEDES AND POSIDONIUS
Physics and Astronomy

The *Caelestia* was read almost exclusively as an astronomical handbook until around 1900,[14] when German classical philologists began to define the historical context of the treatise through *Quellenforschung*, the procedure of "source hunting" by which the ideas in lost works were reconstructed from purportedly later residues.[15] Since Cleomedes admitted using material from Posidonius (n. 3 above), his work was sometimes seen simply as a repository of Posidonian doctrines and treatises, or, in more modified claims, as an amalgam of earlier Stoic literature and Posidonian components.[16] But since almost every Cleomedean sentence could be linked with some Stoic or Posidonian fragment, as well as with passages in manuals of elementary astronomy,[17] interpretations based on the parallels gathered from such sources inevitably left its author identified generically as a post-Posidonian Stoic scholastic with an interest in astronomy. They did not succeed in placing him in any specific historical and intellectual context.

In the early 1920s Karl Reinhardt adopted a more promising approach.[18] He identified what he called the "inner form" of Cleomedes'

14. See Todd (1992) 2–5. Neugebauer (1975) 959–965 continues this tradition. The astronomy in the *Caelestia* did, however, ensure its survival in late antiquity when most other Stoic scholastic material was lost.

15. On this older literature see Todd (2004).

16. Cleomedes' Stoicism generally conforms to the body of doctrine associated with this school's major figure in the Hellenistic period, Chrysippus (280/76–208/4 B.C.); see Algra (1995) 268–270, and the survey at Goulet 9–11. Apart from the theory of lunar illumination in II.4 (see II.4, nn. 1, 8 and 19), Posidonius is not identified as the exclusive source of any of the fundamental theories mentioned in the *Caelestia*, although, as we argue below, he exercised a strong influence on its general principles and methodology. Cf. also n. 52 below.

17. See the parallels and *similia* in Todd's edition of the *Caelestia*, and at Goulet 11–15.

18. See Reinhardt (1921) 183–207, and the recapitulations at Reinhardt (1926) 124, with n. 2, and (1953) 685–686. For some discussion of his views see Todd (2004).

treatise by drawing on a Posidonian fragment (F18EK; translated and discussed in our Appendix), which, along with some associated texts,[19] posits a hierarchical relation between the two major components of the *Caelestia*, physical theory and astronomy.[20]

Physical theory, according to this fragment, deals with matter, causal relations, and teleological explanation, while astronomy is defined as an activity that uses geometry and mathematics to analyze the shape, size, motions, and interactions of the principal heavenly bodies.[21] The two disciplines might address identical topics (for example, the sphericity of the Earth, the size of the Sun, or solar and lunar eclipses), but will conduct their demonstrations in systematically different ways. For while astronomy will be based on observations, it will acknowledge physical theory as foundational. Thus in the all-important explanation of the motion of the heavenly bodies, physical theory supplies the "first principles" *(arkhai)* that astronomy has to adopt and follow.[22]

The distinction, and hierarchical relation, posited between physics and astronomy in F18EK is, as Reinhardt saw, respected throughout the *Caelestia*, where physical theory is acknowledged as defining the cosmology presupposed in astronomical observations and calculations. The treatise in fact opens (I.1.20–149) with a lengthy demonstration that the cosmos

19. On this material see I. G. Kidd (1978a) and *Comm.* 134–136. The texts in question are Diog. Laert. 7.132–133 (= F254 Theiler), Sen. *Ep.* 88.25–28 (F90EK; F447 Theiler), and Strabo 1.1.20 and 2.5.2 (F3b and 3c Theiler). Cf. also Theon *Expos.* 166.4–10 and 188.15–24 (on which see Appendix n. 30) and 199.9–200.12.

20. The reader may now wish to consult the Appendix. The relevance of F18 to the *Caelestia* was also noted at Todd (1989) 1368–1369, and has recently been briefly discussed by Algra (2000) 175–177.

21. Posid. F18.5–18 EK; cf. Sen. *Ep.* 88.26.

22. F18.46–50 EK; see Appendix n. 8, and also Appendix n. 2 for Geminus' concern with the same issue. For the same autonomy of physical theory see Strabo 2.5.2, and Sen. *Ep.* 88.28. F18.46–50 EK and Strabo 2.5.2 also refer to the theory of planetary motion in eccentric circuits found at *Caelestia* II.5.102–141.

(the realm of astronomical observation) is a finite material continuum surrounded by unlimited void. In line with F18EK, its analysis and arguments focus on matter, causal relations, and teleology. Also in that opening chapter, the stability and sphericity of the cosmos are said to be dependent on the centripetal motion of the elements, and while this particular physical theory goes undemonstrated (cf. n. 6 above), its foundational status is obvious, and it is later cited as the basis for the Earth's stability at the center of the cosmos (I.6.41–43).[23] Then at I.5.126–138 the properties of the lighter elements, air and aether, are identified as the cause of the sphericity of the cosmos, while elsewhere the differing density of the elements serves to demonstrate both how the Earth and the heavenly bodies are organically sustained by a mutual interchange of matter (I.8.79–95), and why different heavenly bodies move at different velocities (II.1.334–338). Finally, the lunar theory of II.4–6 consists of an opening chapter on the physical theory of lunar illumination as a prelude to an analysis of lunar phases and eclipses. In all these cases physical causality, as Posidonius claims in general terms in F18EK, serves to define the cosmological structure within which astronomical observations are made and utilized.[24] But the most explicit, and philosophically most interesting, links between the Posidonian program in F18EK and the *Caelestia* are to be found not in physical theory so much as in epistemology and methodology.

23. In fact, this physical assumption determines the way that observations are described throughout the treatise. Without it, the same phenomena (such as the risings and settings of the Sun, as well as the lengths of daytimes and nighttimes) that in I.5–6 are said to entail the sphericity and stable centrality of the Earth could be explained by the rotation of the Earth and the stability of the Sun, as Posidonius recognized in his critique of Heraclides of Pontus at F18.39–42 EK (see Appendix and cf. I.6 n. 14).

24. At the same time, physical causality is exemplified at *Caelestia* I.2–4 through the motion of the Sun, and the diurnal and seasonal changes that it causes. See further Appendix n. 23.

Epistemology and Scientific Method

Physical theory, F18EK argues (lines 30–32 and 42–46), cannot be directly established from “the phenomena” (that is, from the evidence of primarily celestial observations), since, in a famous phrase, these can equally well be “saved” by other “hypotheses.” This undesirable possibility is exemplified (F18.39–42 EK) by the cosmology of a mobile Earth and immobile Sun that had been hypothesized on the basis of the phenomena by Heraclides of Pontus (a pupil of Plato). Posidonius, to borrow language from W. V. O. Quine,[25] can thus be said to have regarded the phenomena as “underdetermining” the theory of the basic structure of the cosmos in that they can support diverse and even conflicting accounts. For Posidonius, “hypothesis” is thus a derogatory term for any theory that, while in principle foundational to cosmology, is mistakenly formulated only on the basis of observations. Posidonius’ aim was to eliminate hypotheses of this type entirely from scientific reasoning.[26]

Cleomedes’ treatment of these central themes in the philosophy of science is, by contrast, indirect and unreflective. He never overtly addresses the status and limitations of astronomy as an observational science, apart from acknowledging at one place (I.1.172–175) that a spherical and geostatic cosmology cannot be established conclusively “from the phenomena” but only from the theory of the centripetal motion of the elements.[27] He is, however, concerned with the way that observations of the heavens, if used uncritically, can lead to false theories, and in one place (I.5.1–6) articulates this concern with explicit reference to the Stoic concept of the criterion of truth.

In Stoicism this criterion is defined as the “cognitive presentation”

25. See Quine (1975).

26. On the special role of F18.32–39 EK in establishing this position see the Appendix 195–199.

27. Cf. n. 23 above, and for the significance of density for the Earth’s sphericity and stability see, respectively, I.5.6–7 and I.6.41–43 (with I.6 n. 14), brief references in chapters that otherwise present arguments based on observations.

(phantasia katalēptikē), which, whether perceptual or based on reasoning,[28] guarantees its own veridicality, or, as it is sometimes described, is "self-certifiable." In effect, it posits a fit between human reason and the content with which it was presented—one that is proof against misleading (or noncognitive) presentations.[29] At an earlier point in his exposition of Stoic philosophy Cleomedes must have introduced this doctrine, probably in an account of the logical theory of which he also presupposes knowledge on the part of his hearers.[30] However, he does not draw close links between general Stoic epistemology and the numerous arguments by which he demonstrates the presuppositions of spherical astronomy (I.5–6 and 8), estimates and calculates the sizes of heavenly bodies (II.1–3), and establishes the central features of lunar theory (II.4–6). But there is sufficient evidence to consider the influence that the general epistemological principles of his philosophical system exercised on this specialized treatise.

As far as his use of the key term *kritērion* is concerned, it serves in four places (I.5.2; II.1.4, 103, 141) to strengthen an objection to the use of sense perceptions to draw immediate and uncritical inferences. Thus in the first instance "sight itself" *(autē hē opsis)* is said to be an invalid criterion on the principle that "it is not the case that everything in fact usually appears to us as it [really] is" (I.5.2–3). So even where sight correctly "suggests," for example, the sphericity of the cosmos (I.5.2), it is still not the criterion of its shape, and obviously not so when someone incorrectly "follows"[31] sight

28. For the distinction between "perceptual" *(aisthētikai)* and "rational" *(logikai)* presentations see Diog. Laert. 7.51 (at *SVF* 2.61). The second category must imply that the presentations are both non-perceptual and based on reasoning.

29. See LS 1.250–251 for this widely accepted interpretation, the use of "self-certifiability" of this presentation, and the coordination between human reasoning and the input it receives.

30. See I.5.1–4 with I.5 n. 3, and II.1.408 with II.1 n. 95.

31. The compound verb for "follow" *(katakolouthein)* is specifically used at I.5.12 and II.1.4 and 140 to describe this mental error of uncritically accepting the apparent properties of an observation. The simple form *akolouthein* is used, at least in this treatise, to describe inferences drawn from observations or theoretical propositions (e.g., I.1.106; cf. *akolouthia* in the present context at I.5.5).

to infer that the Earth is flat (because the horizon appears as a plane) (I.5.11–13), or to claim, as Cleomedes alleges the Epicureans did, that the Sun is the minuscule size it appears to be (II.1.2–5; cf. 102–3 and 140–142). The lengthy polemic over the size of the Sun in II.1 probably reflects a general attack on the Epicurean claim that all appearances are true, which, however charitably interpreted (cf. II.1 n. 3), left its proponents open to the charge of treating celestial observations uncritically. But in the *Caelestia* it was subsumed under a wider program of rejecting "mere sight" as a criterion simply because distances and distorting factors made *all* astronomical observations misleading if taken at face value.[32]

So "sight itself" must be replaced (we learn at I.5.3–6) by demonstrations offered *(a)* "on the basis of what is 'clearer' (that is, of what is presented cognitively *(katalēptikos)* to us" and *(b)* "in accordance with what is patently implied." Now *(a)* points directly to the Stoic criterion of truth, the "cognitive presentation" (although this is the only place where the key term *katalēptikōs* appears in this treatise), while *(b)* defines, at least, programmatically a system of inference (*akolouthia*; cf. n. 30) distinct from, and superior to, an immediate and uncritical response to "sight itself." The argumentation identified in *(b)*, though described somewhat vaguely as "patent" *(phainomenē)*, indicates that conclusions about "things that are not in and of themselves fully displayed" (*ta mē autothen ekphanē*; I.5.4–5) are necessitated just because they are reached through cognitive presentations that are either perceptual or based on reasoning.[33]

Now unfortunately this morsel of evidence, which is offered as a brief prelude to the arguments for the sphericity of the Earth in I.5, represents the sum total of Cleomedes' epistemological and methodological

32. Note II.1.142–143 where he is passionate about "taking to heart" *(enthumeisthai)* the significant damage usually caused when we are misled by superficial sense presentations.

33. See I.5 n. 4 on the context of *(b)*, which accords with Diog. Laert. 7.45 (*SVF* 2.35) where a demonstration is defined as an argument that reaches a conclusion that is relatively less accessible (the term is *katalambanomenon*, from the same root as *katalēptikos*, "cognitive") than its premises.

reflection. But it does offer a basis for judging how far the other arguments in the *Caelestia* for astronomical and cosmological theses extend and elaborate Stoic epistemology, and, in particular, how the Stoic criterion should be interpreted in this context of constructive argumentation.

The Criterion and Demonstrative Procedures

Cleomedes calls his various proofs and counter-arguments "demonstrations" *(apodeixeis)* and "procedures" *(ephodoi)*.[34] The terms are virtually equivalent,[35] though *ephodos* may be a technical term that postdates the early Stoa. Aristotle uses it to describe a process of systematic reasoning,[36] and, along with cognate verbal forms *(ephodeuesthai*, *ephodiazesthai)*, it carries this general sense in various authors of the first and second centuries A.D.[37] The hallmark of the "procedures" in the *Caelestia* is the presence, whether explicit or implicit, of an independently identifiable truth or principle that is the foundation, and so, in effect, the axiom, of the argument.[38] Arguments themselves employ both observational and nonobservational, or theoretical, premises, and, in keeping with the pro-

34. The underlying metaphor (elsewhere the literal sense) is that of being supplied for a journey (cf. 202 n. 30). In its logical use the term therefore describes how a journey from premises to a conclusion starts out and is equipped. Cf. the use of the verb *proienai* ("go forward") at I.5.25 (cf. II.1.226), and *hormasthai* ("start out") at I.5.105, I.6.3, II.1.275 and II.2.6.

35. At I.7.69 an *ephodos* is said to "demonstrate" *(apodeiknunein)* a conclusion.

36. See Arist. *Top.* 105a13–14 where it refers to an "induction" *(epagōgē)* from particulars to universals.

37. See 202 n. 30 for one such example that may be linked to Posidonius. Among authors of the second century A.D., Ptolemy and Sextus Empiricus, for example, occasionally employ this language.

38. For *ephodoi* explicitly identified see I.5.20–29, I.6.1–8, I.7 *passim*, II.1.156, 225–333. In several cases the underlying structure of the reasoning is implicit; see I.5 n. 10, I.7 nn. 9 and 21, II.1 nn. 50, 58, and 73, II.2 n. 9, II.3 n. 11, II.4 nn. 31 and 32, II.5 n. 8, and II.6 n. 7. Cleomedes uses the term *methodos* for procedures once, at II.1.343.

grammatic rejection of "sight itself" as a criterion, lead to conclusions that (as the general Stoic definition of a demonstration prescribes) go beyond what is directly accessible by sense perception.[39]

Procedures vary considerably in their complexity and in the detail with which they are articulated. Some involve direct inferences from the phenomena,[40] others implicit axioms.[41] The exclusionary proofs for the Earth's sphericity and centrality depend on overtly identified principles from Stoic logic (I.5.24–25; I.6.2–4), while others that deal with solar and lunar eclipses rely on optical principles (II.4.119–121; II.5.51–54).[42] The elaborate calculations of the size of the Earth and Sun in I.7 and II.1 ultimately depend on implicit high-level axioms, and also need a greater

39. See n. 33 above. At I.7.5 Cleomedes uses *apodeixis* ("demonstration") with particular reference to the conclusions of procedures that he is about to describe. Arguments can, of course, proceed directly to their conclusions where the phenomena are reliable.

40. See I.1.68–80 (the absence of intracosmic void), I.1.172–191 (the sphericity of the cosmos), I.5.104–113 (the sphericity of the Earth, explicitly contrasted with a formal procedure at I.5.102–105), II.1.225–239 (the Sun's being of significant size; again a contrast with a more elaborate *ephodos* at II.1.240–244), II.2.4–18 (the Sun's being larger than the Earth), II.3.84–99 (the Moon's being the closest planet to the Earth), and II.6.35–78 (the Moon's being eclipsed by falling into the Earth's shadow). But in most of these cases more rigorous demonstrations are, or can be, supplied: e.g., from physical theory in the case of the void and the sphericity of the cosmos (cf. n. 6 above), or in the form of elaborate *ephodoi* in the case of the size of the Sun (at II.1.269–286 and 287–333).

41. Thus the arguments at II.1.144–268 that prove that the Sun is larger than it appears are provisional *ephodoi*, with the underlying axioms omitted as self-evident (see II.1 n. 38). They may have been used as a way of easing students into more elaborate procedures for estimating the size of the Sun (II.1.269–333). At II.1.269, the phrase "the following kind of procedure" *(hē toiautē ephodos)* suggests a deliberate contrast with the more informal kind of demonstration that has preceded.

42. In the *ephodos* at II.4.118–126 that demonstrates the cause of a solar eclipse the axiomatic optical principle (see II.4 nn. 31 and 32) is directly applied to celestial observations (119–121) before being generalized (121–22), rationalized in terms of familiar observations (123–124), and further clarified (124–126).

number of supplementary "assumptions" *(hupotheses)* in the form of definitions, and of numerical and geographical data.[43] In some cases reasoning is even facilitated by purely stipulative hypotheses.[44] The detailed analysis of these arguments can be left to the commentary. Here we shall consider only their relevance to Stoic epistemology, and indicate their probable origins.

Our thesis is that the concept of the criterion of truth is extended in the *Caelestia* from the domain of cognitive, or self-certifiable, presentation to structures of argument within which such presentations are included as premises. Good evidence for this development is that in II.1 Cleomedes winds up a litany of the consequences resulting from uncritically "following" visual sense presentations (as the Epicureans allegedly do when arguing for the minuscule size of the Sun) by saying (II.1.141–142) that "for [bodies] of such size some other criterion must be established." By "criterion" here he cannot mean another *type* of sense presentation (since, as we have seen, he does not regard any visual sense presentation of the heavens as a plausible criterion), but *another way of using the same observational evidence.* This implication is borne out when he immediately introduces a series of procedures in which observations are used, in conjunction with other premises, to reach at first estimates (II.1.144–268), and later specific values (II.1.269–352) for the size of the Sun.

More indirect, but equally compelling, evidence is found in I.7 and II.1, where Cleomedes presents two pairs of procedures that conclude with numerical values (for the sizes of the Earth and Sun respectively), rather than, as is usually the case, demonstrate qualitative or causal the-

43. See I.7 nn. 10 and 20, and II.1 nn. 58 and 73. Bowen (2002) discusses further the two procedures used in I.7.

44. On hypotheses see I.7 nn. 4 and 11, and II.1 n. 57. Hypotheses, or, on occasion, thought experiments, furnish the observational premises used within *ephodoi* at II.1.144–154, 166–170, 255–256 and 304–305, and at II.1.155–166 an observation is derived from a historical report. Whatever its form, an observational statement of some form is always a premise in an *ephodos.*

ses.[45] In I.7 he describes one of them (that of Posidonius) as "less complicated" (I.7.4), and favors the other (that of Eratosthenes) to the extent that he dismisses the view that it is "somewhat more obscure" (I.7.49–50). Now since both Eratosthenes' and Posidonius' procedures depend on *valid* and similar axiomatic foundations (see n. 50), if one of them can be considered superior to the other (as implied by Cleomedes' use of Eratosthenes' value elsewhere, at I.5.272 and II.1.294–295), then, in effect, a criterion of *truth* is applied to their arguments. That seems to be the theoretical background to a qualified scepticism conveyed (at I.7.46–47) about a crucial premise (a terrestrial distance) in Posidonius' calculation.[46]

A similar concern with the truth of the premises in a procedure is evident in Cleomedes' remark (II.1.286) that one of the two calculations he records of the size of the Sun "is considered to carry a greater degree of cognitive reliability" *(enargesterou tinos mallon ekhesthai)* than the first (that of Posidonius) because the latter contains as one of its premises an arbitrary stipulative hypothesis (cf. II.1.282–285)—a defect that makes it "*less* cognitively reliable." Here we can see an extension of the evaluative term *enargēs* (which we have here translated "cognitively reliable," as at II.1.114 and II.6.195) from its application to credible presentations (cf. I.5.4, where it is used interchangeably with *katalēptikos*, the usual term for "cognitive") to the role of characterizing the probative value of a whole argument. Yet the link with general Stoic epistemology can be maintained,

45. It would be implausible for a Stoic to entertain competing demonstrations of theses such as the Earth's sphericity or its centrality in the cosmos, or of the causes of lunar and solar eclipses. As we have seen, such demonstrations can be offered both from observations and from physical theory, though the latter type is considered superior and authoritative (see n. 40). Moreover, within either category of qualitative demonstration, there can be only one way of reasoning correctly. In quantitative demonstrations, or calculations, by contrast, there may be different ways of determining measurements, and an inferior procedure can be rejected without compromising any fundamental physical theory.

46. See I.7 nn. 4 and 11, and Bowen (2002).

since individual premises, whether observational or based on reasoning, must still be "cognitive"[47] if *collectively* they are to entail a true conclusion. But, as we have seen, when doubt is raised about the quality of a given premise, one procedure may be considered superior (namely, closer to the truth) relative to another.

And so, despite the paucity of direct evidence, and the related need for caution in speculative reconstruction, we conclude that the Stoic criterion is adapted in the *Caelestia* to a program of establishing knowledge of astronomical and cosmological matters. This is what we would expect of a work that is a part of a comprehensive and ongoing survey of Stoicism (see nn. 6 and 7), though, as we shall argue next, it also reflects earlier work by Cleomedes' primary source, Posidonius.

Posidonius' Legacy

There are indirect links with what we know of Posidonius that make him a likely source of the procedures found in the *Caelestia*.[48] First, as we have seen, they all reflect Posidonius' general prescription for astronomy in F18EK, in that they presuppose an independently established cosmic structure, and accommodate observations within it, often by using arithmetic and geometry in the manner prescribed for astronomy at F18.15–16 EK. This firm theoretical context guarantees that even if (as in calculations of the sizes of the Earth or heavenly bodies) the procedures may not necessarily yield the truth, they are at least not in conflict with phys-

47. Such premises can be called "presentations" *(phantasiai)*, since in general Stoic epistemology these can be "perceptual" or "rational" *(logikai)*; see n. 28 above.

48. Diog. Laert. 7.54 (*SVF* 1.631; F42EK; LS sect. 40A) reports that Posidonius identified "right reasoning" *(orthos logos)* as a criterion of truth. I. G. Kidd (1978b) 275–276 and 282, and, more fully at (1989), especially 148, links this report with the philosophy of science in F18EK. It could equally well serve as a programmatic rationale for *ephodoi*. LS 2.243, however, legitimately question the reliability of Diogenes' doxography.

ical first principles. Second, since Posidonius had a general interest in logic and the foundations of mathematics,[49] we can assume that it extended to the demonstrations in physical theory and astronomy that he mentions in F18EK. Certainly, at F18.21 EK *hodos*, the root term in *ephodos*, refers to the inferential procedures that are used to demonstrate two theses that are also demonstrated in the *Caelestia:* the sphericity of the Earth (I.5) and the magnitude of the Sun (II.1).

Finally, on a point of detail, in the two pairs of calculations of the size of the Earth and Sun at, respectively, *Caelestia* I.7 and II.1, one member of each pair is attributed to Posidonius (I.7.8–47; II.1.269–285), and all four are founded on the implicit principle that, when two quantities are in a ratio, equimultiples of these quantities taken in corresponding order are in the same ratio. Since, as we learn from Galen, Posidonius studied relational syllogisms that rest on the particularizations of ratios among pairs of quanta in proportion, it is plausible that all of Cleomedes' reports in these particular texts are ultimately derived from Posidonius.[50] This is quite consistent with Cleomedes' preferring, as we have seen, the non-Posidonian alternative in these paired calculations, since Posidonius might have reported other philosophers' views as embodying the axiomatic principle in question.

In conclusion, if *any* source is to be assigned to the conjunction of rigorous reasoning, observations, and physical theory that is so pervasive in the *Caelestia*, the only possible candidate is Posidonius, even if Cleomedean demonstrative procedures are not regarded as Posidonian in every detail.[51] What we can identify is a general Posidonian provenance. As F18EK shows, Posidonius was the only major earlier Stoic who was engaged with the science of astronomy, and who took Stoic epis-

49. See I. G. Kidd (1978b).

50. See Galen *Inst. log.* 18 (F191EK), I.7 nn. 9 and 21, and II.1 nn. 58 and 73. Cf. also I.5 n. 22 and II.3 n. 11.

51. See especially I. 7 nn. 9 and 11 below.

temology into the realms of the philosophy of science. Cleomedes is unquestionably maintaining that general innovation, even if in a less sophisticated and self-conscious manner. *Quellenforschung* may well be a discredited methodology, but in the present case it allows us to identify Cleomedes' *Caelestia* as a remote tribute by a minor Stoic to the ideas of a major predecessor.[52] In fact, without Posidonius, astronomy would probably never have been included in Cleomedes' program of Stoic teaching.

TEXT AND TRANSLATION

Our translation is based on the text in Todd's edition, except for a few changes.[53] Since Cleomedes' scholastic prose is often elliptical (probably reflecting its origins in oral teaching; see n. 5 above), we have introduced a number of supplements, indicated by square brackets. (Angle brackets identify supplements introduced by emendation into the Greek text.) In matters of terminology we have tried to be consistent, but in some cases have had to be flexible.

We have used Arabic numerals for all whole numbers (cardinal and ordinal) above nine, as well as for all numbers (whether whole or fractional) in passages involving calculations or the presentation of measurements and quantified data. In other passages we have followed standard usage and written out common fractions except where they are accompanied by a whole number. For consistency throughout, however,

52. Cleomedean material can therefore be identified as Posidonian in less restrictive terms than are adopted in EK, where a "fragment" has to include Posidonius' name (see most recently I. G. Kidd [1997]). But specific cases must always be judged on their merits; see I.4 n. 33, I.5 n. 22, I.6 n. 10, I.8 n. 39, and II.4 nn. 8 and 19. W. Theiler's collection of Posidonian evidence from Cleomedes is based on Karl Reinhardt's general approach (cf. n. 18 above), and so includes more extensive quotations from the *Caelestia*.

53. See I.4 nn. 8 and 42, II.4 n. 3 and II.6 n. 27.

we have used '1 foot wide' for the term *podiaios* in all cases in which it is applied to the heavenly bodies.

Finally, we have used transliteration to make the original terminology as accessible as possible, and Greek where textual matters are involved, as well as where some nouns appear in oblique cases and verbs in forms other than the infinitive.

Book One of Cleomedes' The Heavens

OUTLINE*

Book One

Chapter 1. The cosmos is a finite and stable structure surrounded by infinite void; the Earth and the heavens are homocentric spherical bodies with corresponding zones of latitude.

Chapter 2. The fixed stars are different from the planets which move within the zodiacal band in a direction opposite to the daily rotation.

Chapter 3. The latitudes of the Earth have differing seasons caused by the motion of the Sun in the zodiacal circle.

Chapter 4. The lengths of daytimes and nighttimes differ at differing latitudes because of the motion of the Sun in the zodiacal circle. (*Digression:* The torrid zone of the Earth is uninhabitable.)

Chapter 5. The shape of the Earth is spherical.

Chapter 6. The Earth is at the center of the cosmos.

Chapter 7. *Digression:* Posidonius' and Eratosthenes' measurements of the circumference of the Earth.

Chapter 8. The size of the Earth is discountable in observations of all heavenly bodies except the Moon.

* The outlines here and at the beginning of Book Two (page 98) are included for the sake of the reader and do not belong to the translation proper. The division of the *Caelestia* into books reflects its original structure as two lecture courses (see II.7 n. 7), but the division into chapters dates only from the editions of the Renaissance, and, while, generally logical, and supported by marginalia in manuscript sources, it has been revised for I.1–4; see Todd ed. *Caelestia Praef.* xx, and also I.1 n. 58, I.2 n. 15, and I.4 n. 1. Cleomedes himself refers to *logoi* ("discussions," perhaps single lectures), which in some cases correspond to our existing chapters; see II.2.29–30 (identifying II.6 as part of II.4–6), II.4.136–137 (identifying II.5), and II.5.150 (identifying II.6).

CHAPTER ONE[1]

3: "Cosmos" is used in many senses, but our present discussion[2] concerns it with reference to its final arrangement,[3] which is defined as follows: a cosmos is a construct formed from the heavens, the Earth, and the natural substances within them.[4] This [cosmos] encompasses all bodies, since, as is demonstrated elsewhere, there is, without qualification, no body existing outside the cosmos.[5] Yet the cosmos is not unlimited, but is limited, as is clear from its being administered throughout by Nature. For it is impossible for Nature to belong to anything unlimited, since Nature must control what it belongs to.

1. On the title of the treatise see Introduction n. 1 above.

2. I.e., the present chapter, which is a preliminary overview of the structure of the cosmos; see further n. 58 below.

3. *diakosmēsis*; cf. *SVF* 2.526–527 and 2.558 where it identifies the distribution of the elements in a fully established cosmos. Cf. also n. 6 below.

4. This is a standard definition; e.g., *SVF* 2.638 (192.35–36), Posid. F14EK, Ps.-Arist. *De mundo* 391b9–10, and *Aratea* 127.14–15.

5. Cleomedes must already have demonstrated that the cosmos is a finite continuum; cf. also lines 126–127 below. At lines 69–73 below, and at I.5.128–134 he alludes to the conditions that maintain this continuum.

11: And that the cosmos has Nature as that which administers it is evident from the following: the ordering of the parts within it;[6] the orderly succession of what comes into existence;[7] the sympathy of the parts in it for one another;[8] the fact that all individual entities are created in relation to something else; and, finally, the fact that everything in the cosmos renders very beneficial services.[9] (These are also properties of individual natural substances.) So since the cosmos has Nature administering <it> throughout, it is itself necessarily limited, whereas what is outside it is a void that extends without limit in every direction. Of this [void] the [part] that is occupied by body is called "place," while that which is not occupied will be void.[10]

20: We shall now briefly summarize [the argument] that there is a void: Every body is necessarily present in something; but the thing that a body is present in, given that it is incorporeal and as such without physical contact,[11] must be distinct from what occupies and fills it; we therefore speak

6. These "parts" are elements (cf. I.4.244 and I.5.8) in an "ordering" (*taxis*; cf. *diataxis* at II.1.399) in the cosmos; see lines 116–119 below (with n. 43), and I.5.126–137.

7. This is elsewhere referred to as the "continued stability" *(diamonē)* or "preservation" *(sōtēria)* of the cosmos; see I.2.2–3, I.8.98–99, and II.1.399.

8. Sympathy in Stoic cosmobiology is a psychophysical interaction between bodies; that is, sympathy is not a metaphorical concept but defines the physical relation between living things.

9. "Provides" *(parekhesthai)* carries an inherently teleological sense, particularly with reference to the Sun's power (e.g., I.3.86, 91, 95, 97, 104; I.4.15; II.1.362 and 371); cf. I.3 n. 17.

10. On the complementary Stoic theories of place, space and void (the most important evidence for which is at *SVF* 2.503–506) see Algra (1995), especially ch. 6 (with Cleomedes discussed at 268–270). On Cleomedes on the void see Todd (1982) and Inwood (1991) 257–259. Inwood tries to draw a distinction between Cleomedes and the earlier Chrysippean theory, but Algra (1995) 269 argues convincingly that Cleomedes is rendering orthodox Stoicism in defining place as that which is occupied by body.

11. "Has no physical contact" *(anaphēs);* cf. Epicur. *Hdt.* 40 and *Pyth.* 86 for the same term used to define incorporeality.

of such a state of subsistence[12]—namely, a capacity to receive body and be occupied—as void.[13]

25: That bodies are present in such a thing can be seen primarily in the case of liquids (i.e., all liquid substance).[14] *(a)* When, for example, we extract the solid from a vessel that contains liquid and some solid body, the liquid converges on the place of the object that has been extracted, and is no longer seen at the same level, but is reduced by an amount equal to the size of the object that was extracted. *(b)* Conversely, if a solid is placed into a vessel full of liquid, the amount of liquid that overflows is equal to the volume of the solid imported, and that would not happen unless the liquid had been present in something that had been filled by it and was capable of being occupied by body.[15] *(c)* In the case of air, too, the same thing must be understood to occur. In fact, air is forced out of the place it occupies whenever a solid occupies that place: when, for example, we pour anything into a vessel,[16] we in return

12. "State of subsistence" *(hupostasis)* is more specific than "existing"; see LS I.164. It is therefore appropriately used of the void, which is "something" (line 57 with n. 22), although conceived of as incorporeal (lines 65–66). Its subsistence comprises positive properties that constitute the way in which it "exists"; see line 68 below, where the generic verb *huparkhein* is used. Elsewhere, the verb related to *hupostasis*, *huphistasthai*, is used both of corporeal existence (II.1.338, 364 and 402), and of a geometrical abstraction (I.3.33).

13. To call void "occupied" here (as at line 18 above) is to treat it as a general concept of space, rather than as the capacity to be occupied by body, its formal definition. See Algra (1995) 69–70, and 269 n. 26.

14. Because of this reference to any type of liquid, we have translated *hudōr* in the passage that follows (as at lines 74–78 below) as "liquid" rather than "water."

15. *(a)* and *(b)* recall the standard argument for place as the "extension" *(diastēma)* between the limits of a container; see Arist. *Phys.* 211b14–17. This commonsense theory, which Aristotle rejected, was widely discussed by his commentators. Philoponus (e.g., *In phys.* 582.19–583.12) essentially adopted the Stoic concept of place as occupied void, although he rejected extracosmic void.

16. Something "solid" can be poured, inasmuch as water is "somewhat compact" (see II.4.36); it is unlikely (cf. n. 18 below) that pliable solids (e.g., salt) are also envisaged.

perceive the air[17] inside it escaping, and especially when the aperture is narrow.[18]

39: We can also conceive of the cosmos itself moving from the place that it currently happens to occupy, and together with this displacement of it we shall also at the same time conceive of the place abandoned by the cosmos as void, and the place into which it is transferred as taken over and occupied by it. The latter [place] must be filled void. If, according to the doctrine of the most accomplished natural philosophers, the whole substance [of the cosmos] is also reduced to fire, it must occupy an immensely larger place, as do solid bodies that are vaporized into fumes.[19] Therefore the place occupied in the conflagration by the substance [of the cosmos] when it expands is currently void, since no body fills it.[20] But if anyone claims that a conflagration does not occur, such a claim does not confute the existence of the void. For even if we merely conceived of the substance [of the cosmos] expanding, that is, being further extended (granted that there is no possible obstacle to such extension), then this very thing into which it would be conceived as entering in its extension would be void, just as of course what it also currently occupies is filled void.

55: So those who claim that there is nothing outside the cosmos are

17. "Air" here translates *pneuma*, which is clearly being used in a non-technical sense; on its technical sense see I.5 nn. 34–35.

18. The vessel involved here may be a clepsydra, which had a narrow aperture at the top and small perforations at the bottom. A liquid in which it was immersed entered through the perforations until the aperture was plugged, and air escaped at the top as this process occurred. Its exit could thus be "perceived in return" (the verb is *anti-lambanesthai*) by touch, and perhaps aurally, if it made, say, a whistling sound.

19. Cf. I.8.83–90 for this principle applied to the Earth.

20. Algra (1995) 321–336 makes the case for Posidonius having believed that the extracosmic void was only large enough to accommodate the expansion of matter caused by the conflagration.

talking nonsense.[21] The very thing that they term "nothing" obviously cannot stand as an impediment to the substance [of the cosmos] as it expands. As a result, when the substance expands, it will occupy something,[22] and what is on each occasion occupied in a natural [process] will be filled by the object that occupies it, and will become its place, which is void that is occupied (i.e., filled) by body. This [filled void][23] will duly become void when the substance [of the cosmos] is again compressed (that is, contracted into a smaller volume).

62: Now just as there is that which has received body, so also there is that which is capable of receiving body; the latter, which can both be filled and abandoned by body, is void. Now it is necessary that the void possess a state of subsistence. But our way of conceiving void is entirely without qualification, since void is incorporeal and without physical contact, since it neither possesses a shape nor has one imposed on it, and is neither acted on in any way nor acts,[24] but is without qualification capable of receiving body.

68: Since the void exists in this way, it is also not present at all within the cosmos. This is clear from the phenomena. For if the substance of the whole cosmos were not naturally linked throughout, then: *(a)* the cosmos could neither be held together and administered throughout by Nature, nor could its parts have any sympathy relative to one another;[25] *(b)* we would also be incapable of seeing and hearing, if the cosmos were not held

21. For Aristotle's position (cf. n. 29 below) reformulated in this way see Alex. Aphr. *Quaest.* 3.12, 105.30–35 and 106.32–107.4 (tr. Sharples [1994] 74–75), and Simplic. *In de caelo* 285.21–24 and *In phys.* 468.1–3.

22. For the void as "something" *(ti)* see *SVF* 2.331, and Brunschwig (1988) 96–99. Lines 64–67 below define its ontological status.

23. Here again (cf. n. 13 above) "void" is being used in the sense of space.

24. "Acting" and "being acted on" *(poiein* and *paskhein)* define body for the Stoics; see *SVF* 1.90 and 2.363. The sense of "acting" here is that of causing an effect; see I.3 n. 17.

25. There is a similar argument at *SVF* 2.543.

together by a single tension (that is, if the pneuma were not naturally linked throughout); for if there were intervening void spaces, our senses would be impeded by them;[26] *(c)* vessels with narrow apertures would also, when inverted in liquids, be filled when the liquid passed through the void spaces; but this does not in fact occur, because the vessels are full of air, and this air cannot be extruded because their apertures are enclosed by liquid.[27] And there are countless other [phenomena] that we need not mention now by which this [thesis] is demonstrated. It is therefore impossible that there be void present within the cosmos.

81: Aristotle and the members of his school do not admit void even outside the cosmos.[28] "The void," they argue, "must be a container of body; but no body exists outside the cosmos; so neither does void."[29] But this is simplistic, and exactly like someone saying that since water cannot be present in places that are dry (i.e., lack water), there can also be no container capable of receiving water.[30] So it should be admitted that "container of a body" is used in two senses: as that which holds body and is filled by it, and as that which is capable of receiving body.

89: "But," they say, "if there were void outside the cosmos, the cosmos would move through it, since it would have nothing that could hold it together and support it."[31] But our response will be that the cosmos

26. Alex. Aphr. *De an libr. mant.* 139.14–17 argues that if light is a body, then if there were an interstitial void, the air would be unevenly illuminated by the light present in the pockets of the void. On pneuma in vision see II.6.178–187, where its peculiar tenuity (or inherently rarefied state; cf. 1.5 n. 34) allows it to be refracted by the water in a full container without causing any overflow.

27. This would not be a problem for liquid poured into an upright vessel, or entering a clepsydra, of which the latter is more likely the situation being described at lines 33–37 above.

28. See line 55–61 above with n. 21.

29. See Arist. *De caelo* 279a12–14, and Simplic. *In de caelo* 284.21–24.

30. On the validity of the notion of an unactualized possibility underlying this counter-claim see Sorabji (1988) 133–135.

31. For this argument see Alex. Aphr. at Simplic. *In de caelo* 286.6–10 and Simplic. *In phys.* 671.4–13 (= *SVF* 2.552). The fact that here and below (see n. 34)

cannot "move" through the void, since it tends toward its own center, and has as down the [direction] toward which it tends;[32] for if the cosmos did not have its center and down as identical, it would "move" through the void[33] (as will be demonstrated in our discussion concerning motion toward the center).

96: They also claim that "if there were void outside the cosmos, the substance [of the cosmos] would, by expanding through it, be scattered and dispersed to an unlimited extent."[34] But our response will be: *(a)* The [substance of the cosmos] cannot be acted on in this way, since it has a holding power that holds it together[35] and thus preserves it. Also, *(b)* the

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Cleomedes responds to the main thrust of arguments that we know were formulated by Alexander of Aphrodisias (fl. ca. A.D. 200) could not in itself prove that he was a contemporary of this Peripatetic (*pace* Algra [1988] 169–171 and [1995] 269; now retracted at Algra [2000] 171–172), since such arguments could have predated Alexander. Cleomedes' connection with Alexander confirms only that he belongs to an era terminating around A.D. 200, when polemics between Stoics and Peripatetics were common; see Introduction with n. 4.

32. See further lines 161–175 below. On this argument see Hahm (1977) 119, Algra (1988) 169–170 and Wolff (1988); cf. also n. 57 below.

33. This conditional sentence (lines 92–94) has sometimes been deleted because of incomplete knowledge of the manuscript tradition; see *Caelestia* Todd ed. ad loc. But it is integral to the reasoning, though when the received text at line 93 says that the cosmos would be borne "downwards" *(katō)*, that qualification can be omitted, since the void has no downward direction; see lines 150–151 below.

34. Cf. Alex. Aphr. at Simplic. *In de caelo* 286.10–23, and at Simplic. *In phys.* 671.8–13 (= *SVF* 2.552); also, derivatively, Themist. *In phys.* 130.13–17 (= *SVF* 2.553). Arist. *Phys.* 215a22–24 had cited dispersal "in all directions" *(pantēi)*, though only Themistius uses the phrase "without limit"/"to an unlimited extent" *(eis apeiron)* found in Cleomedes (at lines 97 and 113–114 below). Alexander did concede that the Stoic "holding power" *(hexis)*, introduced in Cleomedes' response, might prevent the cosmos from splitting into pieces, but thought that power no help when the cosmos was being displaced.

35. As at lines 70 and 72 above, and 98–99 below, *sunekhein* (literally "to hold together") also means "to make continuous" through the physics of the Stoic dynamic continuum, conveyed here by the *hexis* ("the holding power").

enclosing void does not act at all,[36] whereas this [substance] conserves itself through the exercise of its surpassing power,[37] as it is compressed, and again as it expands, in the void, in accordance with its natural changes—expanding into fire at one time, while setting out for the generation of the cosmos at another.[38]

104: Simplistic too is the [Aristotelians'] claim that: "if there is void outside the cosmos, it will have to be unlimited; but if the void outside the cosmos is unlimited, then there will also have to be unlimited body."[39] The reasons are: *(a)* the void's being unlimited does not imply that body is also unlimited, since the concept of the void does not cease anywhere, whereas being limited is in fact included in the notion of body;[40] *(b)* there also cannot be a "holding power" for what is unlimited: for how could something unlimited be held[41] by anything? The [Aristotelians] also make other similar claims.

36. Cf. lines 66–67 and n. 24 above.

37. This power *(dunamis)* surpasses those attributed later to intracosmic bodies such as the Earth (I.8.82–95), the Sun (II.1.357–403), and the Moon (II.3.61–65).

38. The Stoic cosmogony is the result of the evolution of a creative originative fire (e.g., *SVF* 1.107, 171; 2.774, 1027; see Pease [1955] on Cic. *De nat. deor.* 2.57); as such, it can be described as the manifestation of a biological "impetus" (for which Cleomedes uses the verb *hormān*).

39. See Alex. Aphr. at Simplic. *In de caelo* 285.32–286.2 (= *SVF* 2.535), and cf. Arist. *Phys.* 203b25–30.

40. This notion *(ennoia)*, like others in the treatise (I.8.21–26; II.1.155–170; II.3.1–4 and 34–35), is a *preliminary* idea, reached by rudimentary reasoning and requiring further refinement. Thus here we cannot naturally form a notion of body that is not finite (Sorabji [1988] 140 suggests Arist. *Phys.* 204b5–7 as a precedent), but need a demonstration (at lines 133–139 below) that an infinitely enlarged cosmos is inconceivable. In the *Caelestia* Cleomedes shows no interest in the origin of such notions; that is, he does not identify them as "natural" or "common," or see them as "preconceptions" *(prolēpseis)*. (On this feature of Stoic epistemology see Todd [1973] and Scott [1988].) They are comparable to other arguments in the *Caelestia* that are of limited value because they are based only on observations; see Introduction n. 31 and n. 54 below.

41. Perhaps *ekhesthai* (line 110) should be emended to *sunekhesthai*, given that a *hexis* is what makes [the cosmos] continuous (cf. n. 35).

112: That it is necessary that there be void outside the cosmos is evident from what has already been demonstrated. But that it is absolutely necessary that this void extend without limit in every direction from the cosmos, we may learn from the following [principle]: everything that is limited has its limit in something different in kind, different, that is, from the thing that is limited.[42] To take an obvious example: in the whole cosmos air, because it is limited, ceases [to be air] at two bodies different in kind, aether and water.[43] Similarly, the aether ceases at both the air and the void, the water at both the earth and the air, and the earth at the water. Our bodies too are similarly limited by something different in kind, their surface, and this is incorporeal.[44] It is, then, necessary that if the void enclosing the cosmos is limited rather than unlimited, it ceases [to be void] at something different in kind. But nothing different in kind from the void, at which the void ceases, can be conceived of.[45] Therefore the void is unlimited.

123: For even if we did conceive of something different in kind from the void, by which it will be limited, this [other void] will have to be filled, and what fills it will be body. And in this way there will have to

42. In the Atomist-Epicurean tradition this principle is used to demonstrate that extracosmic void is infinite, and that it is occupied by infinitely numerous bodies; see Epicur. *Hdt.* 41, Lucr. 1.958–967, and cf. Arist. *Phys.* 203b20–22.

43. By "ceasing" here Cleomedes means that the elements cease to be called by their given names. However, this does not imply that these four elements are distinct homogeneous bands or layers; in fact the Moon, which is at the "juncture"*(sunaphē)* of air and aether (I.2.37–38; II.3.83–84), has its appearance affected by not being in the "pure" part of the aether (II.3.88–90). On the gradations in the density of the Stoic aether see Todd (2001).

44. On the incorporeality of surface *(epiphaneia)* see Plut. *De comm. not.* 1080E, and the discussions at LS I.163, 165, and 301, and by Brunschwig (1988) 28–30.

45. Another Peripatetic argument (cf. lines 110–111 above) is that such a void is simply an imaginary conception; see Alex. Aphr. *Quaest.* 3.12, 105.27–35, Alex. Aphr. at Simplic. *In de caelo* 285.26–27 and 286.23–27, and Todd (1984). Thorp (1990) 159–164 discusses the Aristotelian basis for this position.

be body outside the cosmos—something that physical theory does not suggest, since all bodies are enclosed by the cosmos.[46] From this it is evident that the external void cannot be limited anywhere. Therefore it is unlimited.

130: Indeed, just as it is thought that everything that is limited is enclosed by something (otherwise it would not be limited), so too the void, if limited, is necessarily enclosed by something. What could this be? A body? Impossible, since there is no body outside the cosmos. But even if there were a [body], it again, since it is limited, will have to be enclosed by a void. And again this void would, if it is not going to be unlimited, be enclosed by another body that would itself in turn be enclosed by another void, since this body too must have boundaries. This [process would go on] to an unlimited extent, and so bodies will come into existence that are unlimited both in number and in size. None of this is possible.[47]

139: Thus if the extracosmic void is limited, and at all events enclosed by something, yet not enclosed by *body*, it will be enclosed by something *in*corporeal. So what will this be? Time? Surface? A *lekton?*[48] Something else just like them? But it is implausible that the void be enclosed by any of these. Indeed, there will have to be another void that encloses it, and this, if it is not unlimited, will have to be enclosed by another void, and this by another to an unlimited extent. So by refusing to admit that the extracosmic void is unlimited, we shall be brought round to the necessity of admitting an unlimited number of distinct voids! That is utterly

46. Cf. lines 5–7 above.

47. For the Epicureans an infinite number of bodies was, of course, possible (see Epicur. *Hdt.* 41–42), although an infinitely large body was not (Epicur. *Hdt.* 57).

48. On extracosmic time as inconceivable see already Arist. *De caelo* 279a14–18. The surface is presumably to be distinguished from a surrounding void, which has been excluded by the preceding argument. An extracosmic *lekton* (literally "the expressible," the carrier of the meaning of a proposition, and an incorporeal; see II.5 n. 18) would have nothing for which it could express a meaning.

absurd.[49] So it is necessary that we agree that the void beyond the cosmos is unlimited.

150: Since the void is unlimited, as well as being incorporeal, it will not have an upwards or a downwards [direction], nor a front, back, right, left, or center, for these directions[50] (seven in number) are observed in relation to bodies. Thus while none of them exists in relation to the void, the cosmos itself, being a body, necessarily has both an upwards and downwards [direction], as well as the remaining directions. So they say that the west is its "front," since its impetus is westward, and that the east is its "back," since it is from there that it proceeds forward.[51] Thus the north will be its "right," and the south its "left."[52]

158: There is nothing obscure about these directions in the cosmos, but the remaining ones [namely, up and down] confused the earlier natural philosophers considerably, and numerous errors occurred in this area, since they were unable to grasp that in the cosmos, which is spherical in shape, the exact center is necessarily downwards from every direction, whereas what extends from the center to the limits and right up to the surface of the sphere is upwards. The two directions coincide in the cosmos (that is, both the center and the downwards direction are identical), though in bodies that are made oblong in shape they are separated, whereas this is not the case with spherical bodies, where instead they coincide. This is because [bodies] with spherical holding powers necessar-

49. This is because the concept of the void is "without qualification" (line 67 above); this would be untrue if blocks of it were separately distinguished.

50. "Directions" *(skheseis);* the term literally means a relational state, appropriately enough since the directions are defined from an arbitrarily defined point.

51. The impetus (*hormē;* cf. n. 38 above) of the cosmos here is that of the sphere composed of aether, which contains all the heavenly bodies; *kosmos* is thus being used, as it often is, in the same sense as *ouranos* (the standard term for "heavens"). This impetus involves a daily rotation from east to west around a fixed central Earth; cf. I.2.1–4.

52. See I.6 n. 7 on these six non-central directions and the arguments for the centrality of the Earth in the cosmos.

ily tend[53] in the direction of their center from their surface, and so have as downwards the [direction] toward which they tend. So the cosmos too, since it is spherical in shape, has the same property, that is, its downwards direction and center are identical because these directions coincide in it at the same [point]. [The sphericity of the cosmos] will be the primary aim of our demonstration in our discussion concerning motion toward the center, but for now we shall demonstrate it in simpler terms, on the basis only of what is presented to us in perception.[54]

176: *(a)* All of us, at whatever latitude of the Earth we may be,[55] clearly see the heavens located above our heads, while everything around them appears to us to be sloping away. Then as we proceed to any other ter-

53. This links the geometry of the sphere and Stoic physical theory. A spherical body will have the kind of "holding power" *(hexis)* that endows it with this shape, and makes it "tend" (*neuein;* cf. lines 91–92 above) in a centripetal direction. For some indication of the physics that applies this principle to the cosmos see I.5.126–138.

54. See I.5.1–6 where the limitations of this argument are noted in more elaborate terms. Proposition *(a)* is a *conclusive* argument only for the sphericity of the *Earth*, based on the evidence of changing horizons (see I.5.107–108 with I.5.49–54), but it can only "suggest" (cf. I.5.1) the sphericity of the cosmos, or, in effect, provide a preliminary notion of it (see n. 40 above).

55. Strictly speaking, the latitude *(klima)* of an observer's locality is defined by the elevation (or inclination) of the north celestial pole above the northern horizon. But (see Figure 1) this *klima* is equal to angle ZOQ, which measures the distance along the observer's meridian from his zenith to the celestial equator. This angle is in turn equal to angle OTE, the observer's latitude, that is, the angular distance measured along a meridian of longitude from the terrestrial equator to the parallel circle passing through the observer's locality; cf. Ptol. *Alm.* 2.6. In standard usage among geographers, the distance from this parallel to the equator can be called a *klima*, and is usually given in stades (e.g., Strabo 2.5.7, 2.5.15–16, and 2.5.39–40), although for Ptolemy it is an arc given in degrees. In his *Geographia* (or *Geographical Directory*) Ptolemy advanced the study of geography by applying scientifically the terms *mēkos* and *platos* (longitude and latitude; the same terms he used in the *Almagest* for celestial coordinates) as coordinates to represent, respectively, east-west and north-south distances reckoned in degrees on (a map of) the Earth; cf. Neugebauer (1975) 934.

restrial latitude at all, what until then appeared to be sloping away is over our heads. This would not occur unless the heavens were located above the Earth in every direction (that is, unless the exact center of the cosmos were downwards, while the [direction] extending from it to the heavens were upwards). *(b)* Also, when on a sea voyage we have no land in sight, the heavens appear to us to be touching the water in a circle at our horizon. But on reaching the place where the heavens appeared to us to be touching the water, they are instead visibly located overhead, and this occurs continuously throughout the voyage. So if it were possible to sail around the whole Earth, or go around it by some other means (assuming that no part of it is uninhabitable),[56] we would learn that the heavens are located above every part of it. And so the center of the cosmos is at once downwards as well as a center. But our lesson concerning the motion of heavy bodies to the center[57] will establish this more effectively.

193:[58] Five parallel circles are drawn in the heavens: one, which we call the equinoctial circle, divides the heavens into two equal parts, while on either side of this are two that are smaller than it, but equal to one another. They are called "tropics," since we draw them through the tropical points of the Sun. Two others are also drawn on either side of these, of which the northern is called "arctic," and the one opposite to it

56. For Cleomedes (lines 210–211 and 266–267 below) the torrid zone *is* uninhabitable.

57. Only in this reference (cf. lines 94–95 and 173–174 above) to this forthcoming demonstration is the phrase "of heavy bodies" added, although it appears in other references to centripetal motion as the physical principle underlying the sphericity of the Earth and the cosmos; see Gem. *Isag.* 16.2, Strabo 2.5.2, and Theon *Expos.* 122.11–16. (Ptol. *Alm.* 1.7, 22.22–23.9 is a related, but special, case; see Wolff [1988] 499 n. 31.) But Cleomedes and these other authors must still mean that *all* the elements in the cosmos have a centripetal motion, i.e., that they are all "heavy" in that sense. See further I.5 n. 38.

58. I.1.193–273 formed a separate chapter in all earlier printed editions. But they are a geographical appendix to ch. 1, while lines 270–273 below form an obvious conclusion, and lines 262–269 complement I.1.3–16 by introducing a teleological principle.

"antarctic." These differ for different [observers] depending on differences in latitude, since they become larger and smaller, and ultimately disappear.[59] Where they do not [both] disappear, one of them must be out of sight, while the other is always visible. Five parts of the Earth are located below the intervals in the heavens that are distinguished by the circles just described:[60] First, the one enclosed by the arctic circle; second, that located below the interval between the arctic circle and the summer tropic; third, the one between the two tropics, which has the equinoctial circle located above it at its exact center; fourth, that between the winter tropic and antarctic circle; fifth, that enclosed by the antarctic circle.

209: The natural philosophers call these parts of the Earth "zones," and say that while each of the outer ones is uninhabitable because of icy cold, the one at the exact center is uninhabitable because of blazing heat, and those on either side of it are temperate since they are each tempered by the torrid and frigid zones adjacent to them. So by further dividing each of these temperate zones into two with respect to the hemisphere thought to be the upper [region of the] Earth, and the one thought to be the lower, they say that there are four inhabited zones.[61] We humans, of whom there are direct reports, inhabit one of these,[62] and the people called "circumhabitants" *(perioikoi)* another. Though the latter are in the same temperate zone as us, they inhabit the region that is thought to be

59. Here, in the next paragraph, and at I.2.79–80 it is assumed that the arctic and antarctic circles are defined; that is, that the observer is not at either pole or at the equator. See Figure 2. Note that Figures 2(a)–(f) are not true perspective drawings. We have instead in this case and others like it chosen to adopt a style of representing the sphere that is traditional in classical astronomy, and distorts perspective in order to facilitate comprehension.

60. On these zones see Arist. *Meteor.* 362a32–362b9, *SVF* 2.649, Ach. *Isag.* 62.20–63.5, *Aratea* 96.23–97.6, and Plin. *NH* 2.172. Posidonius challenged this folk geography; see I.4.90–146.

61. On these see Ach. *Isag.* 65.15–66.25, *Aratea* 97.7–23, and Gem. *Isag.* 15.1–2. See Figure 3.

62. Gem. *Isag.* 16.1 calls such inhabitants "co-habitants" *(sunoikoi).*

below the Earth.[63] The "contrahabitants" *(antoikoi)* inhabit a third zone, and those antipodal to us a fourth, and while they [both] occupy the contratemperate zone, some of them (our contrahabitants, also called "dressed by the shoulder" [*antōmoi*]),[64] occupy the region above the Earth, whereas those occupying the region below the Earth are antipodes.[65] To explain: the footprints of all who walk the Earth must face directly toward the center (that is, the exact center) of the Earth, given that the exact center of the Earth, because of its spherical shape, is downwards. Hence it is not our circumhabitants who become our antipodes, but inhabitants of the contratemperate zone in the region below the Earth—the ones who are located directly opposite us, with their footprints directly opposite ours.[66] The footprints of our circumhabitants do not, however, point toward ours, but toward those of our contrahabitants, so that again these [two groups] become antipodal to one another. Our antipodes become contrahabitants of our circumhabitants, since such relations resemble those of friends and brothers, rather than those of fathers and children, or slaves and masters; that is, they

63. This "region" (*klima* being used in the sense of a broad band of latitudes) is "thought" *(dokoun)* to be "below the Earth" from the perspective of the northern temperate zone. Based on lines 153–158 above, an observer in this zone who looks toward the west has his own region and that of the contrahabitants "above the Earth" (or to his right and left), while the other two regions are below it.

64. A contrahabitant who (following lines 157–158 above) faces west will (to use a military term) be "dressed" (or aligned) to "our" (southern European) left, and we to that person's right, assuming geographical symmetry (see n. 66 below).

65. The use of the Greek "antipodes" as a collective noun for these inhabitants seems preferable to "contrapodes."

66. But while the theory of Nature (see lines 262–269 below) may require *some* equivalently inhabited antipodal zone, it could not guarantee that its geography, and the footprints of its residents, would correspond, unless land masses were suitably distributed in each hemisphere by some teleological principle, as may have been the case for the Stoics (see I.4 n. 32). On the enduring illusion of exact antipodality see Quine (1987) 121–124.

convert,[67] in that we become circumhabitants of our circumhabitants, antipodes of our antipodes, and similarly contrahabitants of our contrahabitants.

235: Yet in relation to each of these [groups] we have something in common, as well as distinct. In relation to our circumhabitants we have in common, first, inhabiting the same temperate zone; second, having winter, summer, and the other seasons at the same time, that is, having identical lengthening and shortening in daytimes and nighttimes.[68] But there is a difference in their daytimes and nighttimes: when it is daytime in our zone, it must be nighttime in theirs, and vice versa, although this is put too loosely. For it is not by precise reckoning that the Sun begins to rise in their zone when it sets in ours, since in that case the nighttime in their zone would be long when the daytime in ours was long, and their seasons, that is, the lengthening and shortening of their daytimes and nighttimes, would be the reverse of ours. But in fact, as the Sun goes round (i.e., encircles) the Earth, which is spherical, it shines its bright light on the [parts] on which it casts its rays each time its course takes it over the Earth's curvatures. So while it is still visible above the Earth in our zone, the circumhabitants necessarily see it rising, given that it goes round an Earth that is spherical in shape, and, as it goes over the Earth's curvatures, it rises at different times for different [observers].

252: In relation to our contrahabitants we have in common: first, that we both occupy the upper hemisphere of the Earth; second, that we have daytimes and nighttimes at the same time, although this is also put too

67. The logical conversion implied here is that of strict reciprocity, whereby aRb is true if and only if bRa. Contrast Arist. *Cat.* 6b28–7a5, where the reciprocity of relatives *(ta pros ti)* can cover the relation, excluded here, between slave and master.

68. "Daytime" *(hēmera)* and "nighttime" *(nux)* will be used for the intervals from sunrise to sunset, and sunset to sunrise, respectively. Cleomedes uses the term *nukhthēmeron* ("interval of a nighttime and a daytime") for the interval from one sunrise to the next; see 1.4 n. 16.

loosely,[69] since there is shortest daytime for them when there is longest daytime for us, and vice versa,[70] given that in relation to them our seasons, that is, the lengthening and shortening of daytimes and nighttimes, are reversed. But we have nothing in common with the antipodes. Instead, everything is reversed: we occupy one another's lower regions of the Earth, and their seasons, that is, their daytimes and nighttimes, in terms of the lengthening and shortening of daytimes, are the reverse of ours.

262: The theory of Nature teaches us that circumhabitants, antipodes, and contrahabitants must exist, since none of these [groups] are described by direct reports.[71] We simply cannot travel to our circumhabitants because the Ocean separating us from them is unnavigable and infested by beasts; nor to the inhabitants of the contratemperate zone, since we cannot traverse the torrid zone. Yet the regions of the Earth that are equally temperate are necessarily inhabited to an equal extent, given that Nature loves Life, and Reason requires that all [parts] of the Earth, where possible, be filled with animal life, both rational and irrational.

270: To be demonstrated next is what causes different parts of the Earth to be frigid, torrid, and temperate;[72] and why for inhabitants of the contratemperate zone the seasons, that is, the lengthening and shortening of the daytimes, are reversed.[73]

69. Cf. lines 240–241 above.

70. It was commonly assumed in antiquity that the shortest nighttime is equal to the shortest daytime, although, as Neugebauer (1969) 158 n. 1 points out, atmospheric conditions make the shortest daytime longer than the shortest nighttime.

71. This "theory of nature" *(phusiologia)* includes the explanation for the cosmos being spherical and geocentric (lines 191–192 above; also I.5.126–138 and II.6.41–43), which in turn determines the Earth's relation to the Sun's motion in the ecliptic (I.2.73–80; cf. II.1.361–386). Cf. also Gem. *Isag.* 16.19–20 on the symmetry of habitable zones in a spherical Earth.

72. See I.2.80–82 where this project is completed.

73. This is the program for I.3; see I.3.111–114; see I.4 n. 1 on its continuation.

CHAPTER TWO

1: As the heavens revolve in a circle above the air and the Earth, and effect this motion as providential for the preservation and continuing stability of the whole cosmos, they also necessarily carry round all the heavenly bodies that they encompass.[1] Of these, then, some have as their motion the simplest kind, since they are revolved by the heavens, and always occupy the same places in the heavens.[2] But others move both with the motion that necessarily accompanies the heavens (they are carried round by them because they are encompassed), and with still another motion based on choice[3] through which they occupy different parts of the heavens at

1. The "heavens" here consist of the element *aithēr* (cf. I.4.87–88), that is, they are a band of rarefied matter with a natural tendency to sphericity (cf. I.5.134–137) and circular motion (*SVF* 2.642). (This sentence therefore supplements the description of the *diakosmēsis* at I.1.3–16.) The term *astra*, which can refer only to the fixed stars, will be translated as "heavenly bodies," when, as here, it refers generically to both the fixed stars and the planets.

2. Hence they are used to define celestial latitudes; see I.3.44–51.

3. This motion is "based on choice" *(kinēsis proairetikē)* because in the Stoic system planets are endowed with reason and thus self-motivated (cf. Cic. *De nat. deor.* 2.43 and 2.58), though such choice is exercised strictly within the limits of the "providential motion" (*kinēsis pronoētikē;* line 2) of the heavens; this, as it were, allows planets some independence relative to the motion of the fixed stars. See further Todd (2001).

different times. This second motion of theirs is slower than the motion of the cosmos, and they also seem to go in the opposite direction to the heavens, since they move from west to east.

12: The first [set of bodies] is called "fixed," but the second "planets," since these appear at different times in different parts of the heavens.[4] The fixed bodies might be likened to passengers who are borne[5] along by a ship, yet remain in their assigned places in relation to the overall space.[6] The planets, by contrast, are like passengers who move in an opposite direction to the ship (toward the stern from positions at the prow) with a relatively slower motion. They could also be likened to ants creeping on the basis of choice on a potter's wheel in a motion opposite to [that of] the wheel.[7]

20: The total number of the fixed bodies is immense,[8] but only seven planets have become known to us,[9] although it is unclear whether there

4. For this general distinction see also *SVF* 2.650. This elementary definition, given the Stoics' preoccupation with etymology (cf. II.5.82–86 and 92–101), was probably designed to draw attention to the literal meanings of *aplanē* and *planōmena/planētai*, "non-wanderers" (sc. fixed) and "wanderers" (sc. planetary).

5. The stars "are borne" (*pheresthai*, in a passive sense), since, unlike the planets (cf. n. 3 above), they do not initiate their own motion. *Pheresthai* switches back to its middle voice sense ("move") in the comparison with the planets.

6. "Space" *(khōra)* is defined by the Stoics (*SVF* 2.503–506) as the larger area within which something has its "place" *(topos)*. See Algra (1995) 263–281 on this concept.

7. For the comparison with displacement in a moving vessel see Ach. *Isag.* 39.16–20 and Hygin. *De astron.* 4.6; and with ants crawling backwards on a wheel Ach. *Isag.* 48.16–18, *Aratea* 97.33–98.1, and Vitruv. *De arch.* 9.1.15. Bodnár (1997) 200 n. 29 links Cleomedes' analogies with his acceptance of planetary motion in eccentric circles (cf. II.5.139–140).

8. For this conventional claim see Arist. *De caelo* 292a11–12, Ps.-Arist. *De mundo* 392a16–17, and Sext. Emp. *PH* 2.90 and 97.

9. For the number of planets as a basic assumption of astronomy see Dercyllides at Theon *Expos.* 200.2–3. (This passage could reflect Posidonian ideas, as I. G. Kidd [1978a] 11 suggests, particularly if Dercyllides can be dated to the first decades of the first century A.D., as Tarrant [1993] 11–12 and 72–76 argues.) On the "Chaldean" planetary order followed here (as opposed to the "Egyptian," in

are still more. The one held to be farthest away, the star of Saturn, named *Phainōn* (The Shining One), completes its own circuit in a period of 30 years in accordance with its motion that is based on choice. Below it is the star of Jupiter, named *Phaethōn* (The Radiant One), which completes its own circuit in a period of 12 years. Below this is *Puroeis* (The Fiery One), the star of Mars, which has a relatively disorderly motion,[10] although it too is held to complete its own circuit in 2 years 5 months.[11] The Sun is thought to be below this, and thus at the center of the other planets.[12] By going round its own circuit in 1 year it demarcates the seasons by this motion, while it provides the days by the motion that accompanies the heavens. Below this is the star of Venus, and it too has a period of 1 year; when it sets later than the Sun, it is called *Hesperos* (Evening Star), but when it rises before it, *Heōsphoros* (Dawn-Bringer), which some also like to call *Phōsphoros* (Light-Bearer). Below Venus is the star of Mercury, named *Stilbōn* (The Gleaming One); they say it goes round its particular circuit in 1 year. Below this is the Moon,[13] closest to the Earth of all the heavenly bodies, in that accepted theory places it at the junction of the air and the aether, which is why its own body is also visibly murky.[14] The illuminated part of it has its luminance from the Sun,

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which the Sun immediately follows the Moon rather than being centrally located) see Préaux (1973) 213–217 and Aujac (1975) 124 n. See also II.7 n. 2. Cleomedes gives the *sidereal* period for each of the seven planets, that is, the time it takes for each planet as seen from the Earth to return to a given star. For the *synodic* planetary periods, that is, the periods from one conjunction (or opposition) with the Sun to the next, see II.7.8–10. On the epithets applied to the planets see Pease (1955) on Cic. *De nat. deor.* 2.52–53.

10. Cf. Plin. *NH* 2.77. This motion is only "relatively" disorderly, given lines 43–46 below, though Cleomedes does not explain why he regards it as such.

11. Gem. *Isag.* 1.26 gives 2 years 6 months for Mars' sidereal period. Others (Cic. *De nat. deor.* 2.53 and Theon *Expos.* 136.8) give just under 2 years. On Copernicus' use of Cleomedes' report see Rosen (1981) 452–453.

12. On the teleological implications of its location see II.1.396–403.

13. On the Moon's proximity to the Earth see II.3.81–101.

14. See II.3.83–84 and II.5.1–7.

since the hemisphere of the Moon that is turned toward the Sun always gets illuminated. The Moon completes its own circuit in 27½ days, and is in conjunction with the Sun in 30 days.

43:[15] All these planets have a motion opposite to the heavens, and so are seen in different [positions] at different times, yet they do not effect a disorderly course, that is, they do not go through random parts of the sky but through what is called "the zodiac," though without going beyond it.[16] The band of the zodiac is at an oblique angle because it is positioned between the tropical circles and equinoctial circle, touching each of the tropical circles at one point, while dividing the equinoctial circle into two equal [parts]. This zodiac has a determinable width, with [parts] in the north, the south, and in between.[17] That is why it is also described by three circles: the central one is called "heliacal,"[18] and the two on either side of it "northern" and "southern."[19] Whereas the other planets approach the northern and southern circles at different times in accordance with the motion based on choice through this zodiac, only the Sun

15. In earlier divisions of Book I, the first sentence of this paragraph (lines 43–46) marked the end of chapter 2, and chapter 3 began with a remark about the zodiacal circle in line 46. But the whole of lines 43–82 offers an effective complement to the preceding account of planetary motion, while returning the discussion to the topic of differences in temperature between terrestrial zones (cf. 73–82 with I.1.270–271). As such, this passage belongs with chapter 2.

16. On the zodiac see Gem. *Isag.* 5.51–53 and Ach. *Isag.* 52.25–55.6. Ptol. *Alm.* 1.8, 27.20–29.16 is less elementary.

17. In I.2 (lines 45, 46, 49, 53, 61, 70 and 73) the "zodiac" is a circular "band" (as we have translated *kuklos* at line 46), whereas *zōidiakos* (with or without *kuklos*) usually refers to the heliacal circle within that band (see next note).

18. Cleomedes does not use the term "ecliptic" *(ekleiptikos);* at II.5.146 it appears in a gloss; see II.5 n. 32. He calls this circle the "zodiacal circle" (I.4.30–31), the "circle that passes through the middle of the zodiacal constellations" (II.5.144–145; II.6.32; II.7.1–2), and "the circle at the middle/center of the zodiacal [band]" (I.4.53–54; II.6.5, 12). At I.4.49–71 he explains that the "heliacal circle" *(hēliakos kuklos)* is properly the circle on which the Sun travels, and that the circle termed "heliacal" (here at line 51) is its trace.

19. See Figure 4(a).

moves exclusively through the central circle, and does not approach either the northern or southern circles.[20] It does approach both the north and south of the heavens as it goes from one solstice to another, but approaches neither [extreme] of the zodiac. Instead, in its course it follows the circle at the exact center of the zodiac; that is why this circle has the name "heliacal."

60: The remaining planets approach north and south both of the heavens, and of the actual zodiac, because they move in it as in a spiral. That is, when they go down from the northern to the southern circle, and from there go back up toward the northern circle, they effect a motion through the zodiac that is neither straight, nor even simple like the Sun, but is like a spiral.[21] And when they move from the northern to the central circle they are said to lower themselves relative to their high position, and when they go through the central circle and approach the southern circle are said to lower themselves relative to their low position.[22] But on going back up from there to the central circle they are said to elevate themselves relative to their low position, and on crossing the central circle and approaching the northern circle, are said to elevate themselves relative to their high position.[23] Because the heavens slope from north to south in the zone that we inhabit,[24] the northern [parts] of the zodiac

20. For a more elaborate analysis of the Sun's motion see I.4.30–43.

21. This spiral-like course, which is confined to the zodiacal band, is the result of the planet's eastward motion along the heliacal circle and of its north-south motion with respect to this same circle.

22. The terms used here for the low and high positions (i.e., the extremal latitudes) of planets in the zodiac are *tapeinōma* and *hupsos.* They sometimes also identify the varying distances to the Earth of planets in their eccentric orbits (II.5.133–141). In astrological contexts, they designate planetary exaltations and depressions, that is, the positions in the heavens from which the planets have their greatest and least effect on an individual (cf., e.g., Ptol. *Tetrabibl.* 1.19.41–42 and Sext. Emp. *AM* 5.35).

23. See Figure 4(b).

24. On this northern latitude see I.3 n. 9. On the northern elevation of the zodiac see I.3.35–43.

are as a result elevated far above the horizon, whereas the southern [parts] are much closer to the horizon.

73: This is how the planets move in the zodiac, but the Sun, by moving in the heavens through the band between the tropics, necessarily makes torrid the terrestrial band below the interval (described above)[25] between the tropics. But when the Sun comes back from the south to the north, it does not go beyond the summer tropic, nor, on going from the summer tropic to the south, does it go beyond the winter tropic. The result is that the zones in the extreme regions[26] are frigid, since they are at the greatest distance from the Sun, whereas the zones below the band between the tropical and arctic [and antarctic] circles are temperate. This [motion of the Sun] is what causes some [regions] of the Earth to be frigid, others torrid, and still others temperate.[27]

25. I.1.194–196.

26. The phrase actually used by Cleomedes at line 78 is "the zones below the Bears" (*αἱ ὑπὸ ταῖς ἄρκτοις ζῶναι*). But since the Bears are a northern constellation, the inclusion of the antarctic zone can perhaps only be justified (as it is by Goulet 192 n. 99) in light of Arist. *Meteor.* 362a32, where the phrase "the other [of the two] Bears" (*ἡ ἑτέρα ἄρκτος*) means "the antarctic region." On the other hand, if *ὑπὸ ταῖς ἄρκτοις* were emended to *ὑπὸ τοῖς ἀρκτικοῖς* ("below the arctic [circles]"), then the reference to both arctic and antarctic zones would be consistent with the unusual use of *ἀρκτικοί* to describe both the arctic and antarctic circles later in the sentence at line 80. We have translated it as "arctic [and antarctic]" there only to prevent confusion, and not as an essential supplement to the text. But, however the text is emended, the meaning intended by Cleomedes in this sentence, and reflected in our translation, is clearer than the language in which it is expressed.

27. Further on the Sun's power see II.1.361–375.

CHAPTER THREE

1: The following is essentially what causes the seasons (i.e., the lengthening of daytimes), to be reversed in the temperate zones. The Earth is spherical in shape, and thus [located] downward from every part of the heavens;[1] as a result its latitudes do not have an identical position relative to the zodiac, but different ones are located below different parts of the heavens. (That is why, as has been demonstrated,[2] they differ also in their temperatures.)

6: So in the mid-torrid zone,[3] which occupies the [latitude] of the Earth at the exact center, the heavens slope neither to the north nor to the south, but maintain a position of complete equilibrium such that each of the poles is observed on the horizon, with no arctic circles existing at this latitude; instead, all the stars set and rise again, and not a single one can be always visible there.[4] But when someone goes from this latitude to the

1. See I.1.159–175.
2. See 1.1.209–269.
3. The phrase "in the torrid zone" *(en tēi diakekaumenēi)* is best translated as "in the mid-torrid zone," in view of the qualifying phrase that follows it, which shows that it refers to the latitude elsewhere defined as "below the equinoctial circle" (lines 52–53 below; cf. I.1.205–206 and I.4.158), i.e., the terrestrial equator.
4. For a formal demonstration of the observational situation at the equator see Theod. *De hab.* 2.16.8–33, and also Figure 2(d).

temperate zones the position of the heavens appears increasingly different: one of the poles becomes concealed, while the other becomes elevated (that is, raised above the horizon). So for anyone coming to our temperate zone from the mid-torrid zone the south pole would go out of sight, since in the course of the journey it would be obstructed by the curvature of the Earth. The north pole, by contrast, would be elevated high above the horizon. But if we hypothesize someone traveling from the mid-torrid zone to the contratemperate zone, the opposite would occur: the south pole would be elevated above the horizon, and the north pole would go out of sight.[5]

22: So let us hypothesize someone coming from the mid-torrid zone[6] to our temperate zone. Now when that person is still [directly] below the equinoctial circle, each of the poles will be seen on the horizon, and no star will be either out of sight or always visible, and so there will also be no arctic circles. (An arctic circle must exist at our latitude to enclose the stars that are always visible, and an antarctic one to enclose those that are [always] concealed.) But someone who initiates the process of reaching here[7] from the south will necessarily have the south pole concealed by the curvature of the Earth, and the north pole proportionately elevated. And in this way the heavens assume for that person a slope from the north to the south: that is, of the stars near the poles some will go out of sight, others will be always visible, and the arctic circles enclosing these stars will exist with their slope necessarily changing in accordance with the forward direction of the journey. Since en route the heavens continually assume a position that is increasingly sloped, the northern parts of

5. Cf. the earlier account of the observations of changing horizons at I.1.176–182, where they served as prima facie evidence of the sphericity of the cosmos. At I.5.107–111 they help to demonstrate conclusively the sphericity of the Earth; see Figure 5.

6. Because this zone is uninhabitable (cf. I.1.187–189 and 265–267), this has to be a hypothesis.

7. "Here" is the latitude of Greece (cf. line 39 with n. 9 below), used to identify the north.

the zodiac will be seen as high (that is, elevated well above the horizon), and the southern parts as low (that is, much closer to the horizon).[8] Also, for someone who goes to the north from the south in this way and arrives at the terrestrial latitude of Greece, at which Aratus also composed his poem *The Phaenomena*, "the head of Draco" and "the feet of Helice" will be touching the horizon.[9] Also, the circle enclosing the stars that are [always] concealed will necessarily become equal to the size of the arctic circle.

44: Given that the heavens slope in this way, we must next imagine that each of the fixed stars, as it is revolved along with the heavens around its own center, describes a circle.[10] Now these circles are all parallel, and while the equinoctial circle is the largest of them, the smallest are those around the poles of the cosmos. Thus the circles proceeding from the [poles] to the equinoctial circle will become larger in proportion to their distance from the poles, whereas those proceeding from the equinoctial circle to the poles will become smaller in proportion to their distance from the equinoctial circle. At the latitude below the equinoctial circle all these circles (the greatest, smallest, and intermediate ones) have half-sections above as well as below the Earth.[11]

8. These definitions may be needed because at I.2.62–69 (cf. I.2 n. 22) "highness" and "lowness" described planetary motion in the zodiac rather than the changing appearance of the zodiac at different latitudes. I.2.69–72 only briefly foreshadowed this additional sense.

9. At Arat. *Phaen.* 58–62 (cf. *Schol. in Arat. vet.* 98.7–8) Draco is said to look "as if it is inclined towards the tip of Helice's tail: the mouth and the right temple are in a very straight line with the tip of the tail. The head of Draco passes through the point where the end of settings and the start of risings blend with each other" (tr. D. Kidd [1997] 77). Draco is at 54°N and so the latitude in question here is 36°N, that of Rhodes (cf. Ptol. *Alm.* 2.6, 109.5–10), the fourth of the seven canonical locations that mark latitudes in the northern hemisphere; see further Neugebauer (1975) 44, and cf. D. Kidd (1997) 199–200.

10. Each of these circles is called a "day-circle."

11. See Figure 2(d).

54: When someone reaches our zone from that latitude, then just as the north pole is elevated and the heavens slope, so these circles too no longer maintain the same position relative [to the Earth], but the equinoctial circle (a great circle that divides the heavens into two equal [parts]), has precisely half remaining above the Earth, and half below it. (That is because every circle that divides the heavens into two equal parts is either the horizon, or is divided into two equal [parts] by the horizon, so that it has half always visible above the Earth, and half concealed.) Thus since the equinoctial circle is a great circle, it also maintains the same position relative [to the Earth] even in the temperate zones, whereas the [successive circles] that proceed from it toward the poles do not. Instead, all the larger sections of the [circles] that proceed toward the north pole are necessarily above the Earth, since they are more elevated in our temperate zone, whereas the smaller sections are below the Earth. All the circles that proceed toward the south pole, by contrast, have larger sections below the Earth and smaller ones above it, at least [in our zone] where the whole antarctic circle <must> also <be> concealed, whereas the arctic circle is always visible.[12]

69: That is the situation in our temperate zone, but in the contratemperate zone the situation is reversed: that is, what is low [on the horizon][13] for us is high there, and vice versa, since they have the heavens sloping from the south to the north. Someone traveling there from the [latitude] below the equinoctial circle has the north pole going out of sight, and the south pole elevated, and so what is high for them is low for us, and vice versa. Thus they also have the arctic circle concealed, while the opposite circle is elevated in an amount equal [to the lowering of its counterpart].[14]

12. Our translation follows a Byzantine paraphrase; see the apparatus criticus at *Caelestia* Todd ed. I.3.67–68. See also Figure 5 (b).

13. See the definitions of "high" and "low" at lines 36–38 above, and cf. n. 8 above.

14. See Figure 5(c).

76:[15] Given all this, the Sun will obviously touch[16] all the [day-]circles between the tropics as it effects its course through the zodiac from one solstice to another. So when it touches the winter tropic as it goes from north to south, it causes our shortest daytime.[17] That is because of all the circles which the Sun touches this one has [for us] the largest section below the Earth and the smallest above it, and so [on touching it] the Sun necessarily causes the shortest daytime and longest nighttime in our temperate zone. But when, after touching the winter tropic, it again turns back toward us, then as it goes up toward the more elevated parts of the heavens, it continually encounters circles that have sections above the Earth larger than the section of the winter tropic [that is above the Earth]. In this way it provides a daytime that proportionately increases, while still remaining shorter than the nighttime, as long as the Sun's course is toward the equinoctial circle. But when the Sun touches the equinoctial circle, where the [sections] above and below the Earth are equal, it causes the [vernal] equinox. Finally, as the Sun goes up from the equinoctial circle to the summer tropic, it also necessarily provides daytimes that are longer than nighttimes when it encounters circles that have larger sections above the Earth. Such lengthening proceeds until the Sun approaches the summer circle, which, of all the circles that the Sun touches at our latitude, has the largest section above

15. This paragraph enlarges on I.2.73–78.

16. Since the heavenly bodies appear to be equidistant from the Earth, they also appear to move in the same plane, and on, as it were, the inner surface of a relatively small hemisphere (cf. II.1.85–86 with II.1 n. 20). It is within this conceptual framework that the Sun can be said to "touch" the day-circles.

17. Here and elsewhere we translate *poiein* as "cause." This is justified by the association of this verb with *aitia* (the standard term for "cause") in an identical context dealing with solar "power" at II.1.365–367; cf. also Posid. F18.26 EK for the related phrase *poiētikē dunamis* similarly associated with *aitia* in a more general context (see Appendix n. 23). The causality in question is also teleological (cf. F18.22 EK), as the use of "provide" *(parekhetai)* (cf. I.1 n. 9), and "bring to completion" *(epitelein)* in this context (e.g., I.2.31 and I.4.2) indicates. On Posidonius' interest in aetiology see, for example, T85EK with Kidd *Comm.* 72–74.

the Earth. In this way it provides our longest daytime at the summer solstice.

95: But <when> it goes down to the south from here, and encounters circles that have sections above the Earth that are proportionately smaller than that of the summer tropic, it provides a shorter daytime, although the daytime remains longer than the nighttime until the Sun approaches the equinoctial circle. But when it causes the autumnal equinox by touching the equinoctial circle, it immediately goes through it[18] and touches circles that have smaller sections above the Earth, and so after the autumnal equinox nighttimes become longer than daytimes. The daytime gets continually shorter until the Sun approaches the winter tropic, while the nighttime remains longer than the daytime until, after the solstice at the winter tropic, the Sun provides a daytime that gets longer by turning back from this tropic to approach the equinoctial circle and causes the vernal equinox.

107: This is the situation with the parallel circles just described, and since those circles that are low [on the horizon] for us are high (i.e., elevated) for those in the contratemperate zone, and vice versa, our summer tropic is thus also their winter tropic through having its smallest section above the Earth, whereas their summer tropic is our winter tropic.[19] This [contrast] is the cause of the seasons' (that is, of the lengthenings and shortenings of daytimes) being reversed in the contratemperate zones, and it is the general cause of the universal lengthening and shortening of daytimes and nighttimes.[20] Nothing like this, however, occurs in the mid-torrid zone where instead there is a permanent equinox, since equal parts of all the parallel circles are above and below the Earth.[21]

18. At I.4.37–43 this motion is linked with the angle of the ecliptic at the equinoctial circle.

19. See Figure 5(b)–(c).

20. This completes the plan outlined at I.1.270–273. It will be refined in I.4 (cf. especially lines 232–239) with reference to the relation between nighttimes and daytimes considered over the period of the whole year.

21. Cf. lines 51–54 above, and I.4.234–235.

CHAPTER FOUR[1]

1: By effecting its motion based on choice through the zodiac the Sun occupies different parts of it at different times; in that way it completes [the cycle of] the seasons. It causes the summer solstice when, in very close proximity to our habitation,[2] it describes its northernmost circle and causes the longest daytime and the shortest nighttime. It causes the winter solstice when, on getting farthest from our habitation (that is, in its lowest position in relation to our horizon), it describes its southernmost circle, and causes the longest nighttime of the year and shortest daytime. It causes the vernal equinox when, in its course from the winter solstice to the north and the summer tropic, and located precisely halfway between both of them in its course, it describes a circle that divides the heavens into two equal parts and causes daytime to be equal to nighttime. It causes the autumnal equinox when, on turning back from the

1. This chapter recapitulates I.3.76–106 before offering a more elaborate analysis (lines 18–89) of what causes variations in daytimes and nighttimes, a topic it later (lines 147–196) pursues with special reference to the northern hemisphere. Despite a digression (lines 90–146) on Posidonius' account of terrestrial zones, this discussion is as coherent as, for example, II.1, and is kept as a single unit here instead of being divided, as it has traditionally been, into four separate chapters.

2. On the latitude of this habitation see I.3 n. 9.

summer tropic to the south and the winter tropic, and likewise on getting precisely halfway between the two, it describes the same equinoctial circle. [To sum up], the Sun provides daytimes that increase in length when it turns back from the winter tropic to the northern [parts] of the heavens, and [daytimes] that decrease in length when it goes down in the opposite direction from the summer tropic to the south and the winter tropic.

18:[3] The lengthening of daytimes and nighttimes does not add and subtract an equal amount during each [complete] day,[4] but when the daytime starts to be lengthened, then in the first month it grows longer by $\frac{1}{12}$ of the whole amount by which the longest daytime exceeds the shortest; in the second by $\frac{1}{6}$ [of that amount]; in the third by $\frac{1}{4}$; in the fourth by $\frac{1}{4}$ again; in the fifth by $\frac{1}{6}$; and in the sixth by $\frac{1}{12}$. Thus if the longest daytime exceeds the shortest by 6 hours,[5] then in the first month $\frac{1}{2}$ hour will be added to the daytime; in the second 1 hour; in the third $1\frac{1}{2}$ hours, so that the addition amounts to 3 hours in the three-month period; and in the fourth month $1\frac{1}{2}$ hours will again be added; in the fifth 1 hour; in the final month $\frac{1}{2}$ hour. In this way the 6 hours by which the longest daytime exceeds the shortest will reach their total.

30:[6] The cause of these additions' being unequal is the following. The zodiacal circle[7] through which the Sun effects its course is slanted and so

3. With this paragraph cf. Gem. *Isag.* 6.29–50 and Aujac (1975) 38 n. 1.

4. This "day" *(hēmera)* is the period defined by two successive sunsets, what the Greeks usually called a *nukhthēmeron* (the term used at lines 72–89 below). Our terms "daytime" and "nighttime" for *hēmera* and *nux* (cf. I.1 n. 68) distinguish the periods of solar illumination and darkness within any such "day."

5. This is the situation at the Hellespont (54°N); see Ach. *Isag.* 57.2–6, Hipparch. *In Arat. et Eudox. Phaen.* 1.3.7 (26.16–23), *Schol. in Arat. vet.* 304.3–5 and 305.9–306.5, and Ptol. *Alm.* 2.6, 109.17–18. Cf. II.1.442, where 9 hours is given for the shortest nighttime at the Hellespont.

6. With this paragraph cf. Gem. *Isag.* 6.34–39.

7. That is, the central circle of the zodiacal band, as is explained at lines 52–53 below. The Sun appears to go "through" it, in the sense that it follows it in its course. That is, this zodiacal circle is the trace of the heliacal circle on the zodiacal band, and is sometimes itself called the "heliacal circle"; cf. I.2.46–52, and I.2 n. 18.

intersects with the equinoctial circle at two points, while touching each of the tropics at one point. It intersects with the equinoctial circle and adjacent parallel circles more directly,[8] but abuts on the tropical circles more obliquely, that is, at a more inclined [angle]. Because it produces acute angles in this latter way, it becomes the cause of [the Sun's] approaching and distancing itself from the tropics more slowly. The Sun, that is, as it effects its lengthy course through the zodiacal circle, distances itself from the tropics more slowly, whereas at the equinoctial circle, where the zodiacal circle is more upright, it effects its approach and withdrawal from it more abruptly.[9] Providence, in other words, has marvellously fashioned the relation of the zodiacal circle to the tropics in such

8. Here we have revised Todd's text by deleting at line 34 a phrase seemingly designed to explain "more directly" (*ὀρθότερος*) in the same way as "more obliquely" (*πλαγιώτερος*), which is explained in the next clause by the phrase "at a more inclined [angle]" (*ἐπὶ πλέον ἐγκλινόμενος*). The deleted phrase is *καὶ ὀλίγου δεῖν πρὸς ὀρθὰς γωνίας*, "i.e., almost at right angles." But this is obviously untrue of the angle in question, which is approximately 23½°. Neugebauer (1975) 961 n. 4 recognized the problem, and proposed deleting *γωνίας* ("angles") and translating the phrase as "almost as a straight line." He explained this as meaning "under a constant angle, in contrast to a changing direction farther away until tangential contact with the tropics," and noted an identical Latin expression ("paene directim") at Mart. Cap. 8.878. However, the common phrase *πρὸς ὀρθάς* would then have to be used unprecedentedly to mean *πρὸς ὀρθὰς γραμμάς*, whereas *γωνίας* is normally understood in this phrase, as at *Caelestia* II.5.70. Also, the Greek for "in relation to a straight line" would presumably be *πρὸς εὐθεῖαν γραμμήν*, by analogy with the standard phrase for "in a straight line," *ἐπ' εὐθείας* (*γραμμῆς*) (e.g., II.6.182). The adjective *ὀρθός* also normally refers to lines that are perpendicular to one another. We suspect that *καὶ ὀλίγου δεῖν πρὸς ὀρθὰς γωνίας* was derived from a gloss, designed to balance the genuine gloss on *πλαγιώτερος*, its intrusive status suggested by its awkward location after the main verb *τέμνει*. (For another deleted gloss see II.5.145–146, with II.5 n. 32.) The glossator was perhaps either impressed (consult Figure 6) by the near equality of the angles of intersection at C and D, or else was exaggerating the angle of intersection at these points in order to sharpen the contrast with what happens at A and B. In either case, the thought is so poorly expressed that we decline to attribute it to Cleomedes.

9. See Figure 6.

a way as to ensure that changes in the seasons occur imperceptibly rather than abruptly.[10]

44: The time intervals between the tropics and the equinoctial circle are not equal either: from the vernal equinox to the summer solstice there are 94½ days; from the summer solstice to the autumn equinox 92½ days; from this equinox to the winter solstice 88; and from the winter solstice to the vernal equinox 90¼.[11]

49: So the problem arises: given that the four quarters of the zodiacal circle are equal, why does the Sun not complete its passage through them in an equal time? Now the answer to be given is that if the Sun effected its course through the zodiacal circle itself, it would go through all its parts in an equal time. But the heliacal circle is in fact located below the central circle of the zodiacal band, and at a position much closer to the Earth. Yet if, despite being located below the zodiacal circle, the heliacal circle had the same center as the zodiacal circle, the Sun would also go through the four parts of its own circle in an equal time, since then the diameters drawn out from the tropical and equinoctial [points of the zodiacal circle] would also divide the heliacal circle into four equal parts. But in fact [these two circles] do not happen to have the center. Instead, the heliacal circle is eccentric [relative to the zodiacal circle], and for this reason is not divided into four equal [parts] by the diameters just mentioned. Rather, its arcs are unequal, since only circles with identical centers have arcs equally divided by diameters, whereas circles that do not have the same centers do not.[12]

62: So since the heliacal circle is eccentric, then if it is divided into

10. Cf. II.1.396–399, and Cic. *De nat. deor.* 2.49.

11. See Figure 7(a). Other sources report a year of 365¼ days, with 88⅛ days in the period from the autumn equinox to the summer solstice, and 90⅛ days in that from the winter solstice to the spring equinox. See Gem. *Isag.* 1.13–16, Ptol. *Alm.* 3.4, 233.21–24 and 237.20–238.4 (with Hipparchus' prior authority invoked at 238.3–4), and Theon *Expos.* 153.6–12.

12. For similar demonstrations see Gem. *Isag.* 1.31–34, Theon *Expos.* 153.16–158.11, and Mart. Cap. 8.848–849.

twelve [parts], just like the zodiacal circle, there will be unequal sections of the heliacal circle located below equal sections of the zodiacal circle. Its largest section will be that located below Gemini, its smallest that below Sagittarius:[13] that is also why [the Sun] goes through Sagittarius in the shortest period, but through Gemini in the lengthiest, since it is at its greatest height in Gemini, but closest to the Earth in Sagittarius, while proportionately [distant] in the other signs. So consequently the Sun's circuit is also eccentric since it does not always move at the same height,[14] but in accordance with its course it moves both on high and back toward [points] closer to the Earth.[15]

72:[16] Nor are all the intervals of a nighttime and a daytime equal to

13. A *zōidion* may be either a zodiacal constellation or a zodiacal sign (a *dōdekatēmorion* or one-twelfth part of the zodiacal circle; see n. 17 below). Here Gemini and Sagittarius are zodiacal signs.

14. "Height," here and elsewhere, translates *hupsos*, which in cases such as this refers to the distance of a celestial body from the center of the cosmos, the Earth.

15. See Figure 7(b).

16. As noted in the Introduction (nn. 11 and 12) in connection with the dating of the *Caelestia*, the argument at lines 72–80 here parallels Gem. *Isag.* 6.1–4, and both passages offer a less sophisticated analysis of day lengths than Ptolemy's at *Almagest* 3.9. Also, Geminus uses the periphrasis "a nighttime and a daytime added together" *(to sunamphoteron nux kai hēmera)* instead of Cleomedes' term "interval of a nighttime and a daytime" *(nukhthēmeron)*. His passage is as follows: "[1] 'Day' is used in two senses: in one sense it is the interval of time from a rising of the Sun to a setting, but in the other sense 'day' is used for the interval of time from one rising of the Sun to the next. [2] In the second sense the day is [identical with] the revolution of the heavens *and* the rising of the arc that the Sun traverses as it moves in the direction opposite to the heavens during their revolution. [3] That explains why a nighttime and a daytime added together is also not precisely equal to every nighttime and daytime. Instead, while their lengths are equal relative to perception, relative to precise reckoning there is some slight and imperceptible variation. [4] The reason is that while the revolutions of the heavens are in equal intervals of time, the risings of the arcs that the Sun traverses during the revolution of the heavens are not. That explains why a nighttime and a daytime added together is not <equal> to every nighttime and

one another by precise reckoning, as is supposed, but only in relation to perception. That is because the revolution of the heavens themselves is necessarily less than every interval of a nighttime and a daytime, given that in a whole course the heavens complete their own circuit more quickly than in the interval of a nighttime and daytime that the Sun proceeds through as it goes in the opposite direction to the heavens. For when the heavens have come right round to the same point, the Sun is not yet observed in the east; instead it is only when the arc of the circle that the Sun in accordance with its motion based on choice completes during the interval of a nighttime and a daytime is elevated that it too is seen in the east. So if all the *dōdekatēmoria*[17] of the zodiacal circle, which are equal, also rose in an equal time, every interval of a nighttime and a daytime would consequently be equal as well. But in fact the summer signs rise upright and set obliquely, and as they rise upright the period of their rising is longer, and so the parts of them through which the Sun goes in the interval of a nighttime and a daytime rise proportionately more slowly.[18] But the opposite occurs with the winter signs.[19] Thus the revolutions of the aether are equal, but the intervals of a nighttime and a daytime are not, at least on the most precise reckoning.

90: The Sun, as we have said,[20] approaches the tropics and withdraws from them rather slowly, and for that reason spends a longer time near

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daytime added together." In the final sentence of sect. [4] we delete *pasa* ("every") before the first use of "a nighttime and a daytime added together" to create the required parallel between this sentence and the first sentence of sect. [3]. Also, the supplement "<equal>" should have the form *isē* in Greek, not *ison* (Aujac), again as in the first sentence of [3].

17. As the technical term for the zodiacal signs, that is, for those twelfth parts of the zodiacal circle that are named after certain constellations, we leave *dōdekatēmorion* transliterated, as also at I.7.21, I.8.38, and II.1.319 and 328. For the definition and identification of the *dōdekatēmoria* as zodiacal signs see Gem. *Isag.* 1.1–4.

18. See Figure 8.

19. See Ptol. *Alm.* 2.7 on rising times.

20. Lines 30–40 above.

them. Also, the parts below the tropics are not uninhabitable, nor are those still further south. Syene[21] is in fact located [directly] below the summer tropic,[22] and Ethiopia farther south than this.[23] Taking his key from this [evidence], Posidonius believed that the whole latitude below the equinoctial circle was also temperate.[24] And where the reputable natural philosophers had claimed that there were five terrestrial zones, he alone claimed that the one they called "torrid" was inhabited and temperate. That is, he argued that[25] *(a)* if the [latitudes] below the tropics are not uninhabitable, nor those still farther within them,[26] despite the Sun's spending longer there, how could the [latitudes directly] below the equinoctial circle not be much *more* temperate, since the Sun approaches this circle rapidly and again distances itself at an equal speed, and does not spend a prolonged time at that latitude, when moreover, as he says, *(b)* the nighttime there is always equal to the daytime, and for this reason has a length appropriate for cooling <the air>? *(c)* Since this air is also in the exact center (i.e., most voluminous [part]) of the [nocturnal] shadow, there will be rains and winds that can cool the air, because even in Ethiopia rains reportedly fall continuously in the summer, and espe-

21. Its contemporary name is Aswan. The same location is assigned it at Plut. *De def. or.* 411A and Strabo 2.5.7. See also I.7.71–72.

22. See I.5.59–60; I.7.71–72; II.1.211–212 and 270.

23. The Ethiopians (located in modern Sudan) were often identified (e.g., by Homer *Odyssey* 1.22–24; cf. *Iliad* 1.423) as the most equatorial race in the known world, just as they had been the most peripheral on a flat Earth; see Gem. *Isag.* 16.28 with Aujac (1975) 152 n. 3.

24. Posidonius, in addition to lines 90–131 here (= F210EK), addressed issues involving zones at F49.1–145 EK; cf. also F209 and F211EK. His treatise on this subject, *On the Ocean*, was known to Strabo.

25. The three explanations that follow may be "alternative possible hypotheses" (Kidd *Comm.* 136), but they are not mutually incompatible as are the explanations of paradoxical eclipses anonymously proposed at II.6.168–177 (see II.6 n. 21). I. G. Kidd (1978a) 14 mistakenly tries to use such multiple explanations to support his interpretation of Posidonius' philosophy of science in F18EK as an activity based on hypotheses. See Appendix, especially n. 7.

26. I.e., closer to the equinoctial circle.

cially at its height, and these are also thought to be the source from which the Nile floods during the summer.[27]

109: That, then, is Posidonius' position. And if this is the situation with the regions below the equinoctial circle, then the seasons will have to occur there twice a year, since the Sun is certainly at their zenith twice, inasmuch as it causes two equinoxes.[28]

113: Those who oppose this opinion of Posidonius argue [as follows]. *(a)* As far as the Sun's spending longer at the tropics is concerned, his doctrine would have to be sound. Yet, in addition, the Sun distances itself a considerable amount from the tropics, and so the air below them also cools off a considerable amount. As a result, those latitudes can be inhabited. But it distances itself just slightly from the equinoctial circle (which is halfway between the tropics), and effects a rapid reversal of direction toward it.[29] *(b)* The [latitudes] below the tropics receive annual winds from the frigid zones, and these moderate the extreme heat from the Sun by cooling the air.[30] But they cannot penetrate as far as the

27. On *(c)* see Strabo 2.3.3 (F49.51–61 EK) and 2.3.3 (F49.134–135 EK).

28. This parenthesis could be an implication that Posidonius himself drew, or Cleomedes' interjection, based on I.3.88–89 and 98–106, and lines 8–13 above, where the vernal and autumnal equinoxes are distinguished. The reasoning is that although the "seasons" at the terrestrial equator are not distinguishable by the usual criterion of the length of the daytimes and nighttimes (defined by the Sun's return overhead and by its departure; cf. lines 234–235 below), they are definably different in temperature, and in this respect form two pairs of seasons which are defined by the Sun's return to an equinox and departure for a solstice. This claim reinforces the arguments for equatorial habitability in *(a)–(c)* that precede, but in such general terms that it is probably best taken as a Cleomedean aside.

29. Since the distances involved here depend on the size of the Earth, this observation may reflect some debate about the distance between the terrestrial tropics and equator; see Strabo 2.2.2 (Posid. F49.10–36 EK) with Kidd *Comm.* 223–228.

30. See Strabo 3.2.5 (Posid. T22EK) on Posidonius' account of annual ("etesian") winds. At *Aratea* 97.1–6 this argument is attributed to an earlier Stoic, Panaetius (ca. 185–109 B.C.).

equinoctial circle. If they do, then the Sun, given the length of its course, will make them hot, indeed flaming hot. *(c)* The equality [below the equinoctial circle] of nighttime to daytime would not by itself have the power to cool the air there, given that the Sun has an indefinable power, and at all times sends out its ray toward that latitude in a perpendicular and intense form, since it certainly does not significantly slope away from that latitude. (The natural philosophers suppose that most of the Great Sea, which is centrally placed in order to nourish the heavenly bodies,[31] is inserted at this latitude.)[32] Thus in this case Posidonius does not seem to adopt the correct view.

132: But on [Posidonius'] hypothesis[33] that the whole Earth is inhabited, some habitations will be encircled with shadows *(periskioi)*, others shadowed unidirectionally *(heteroskioi)*, and others shadowed bidirectionally *(amphiskioi)*. Encircled with shadows are those habitations below the poles where the year will be [equally] divided into daytime and nighttime, the equator will be the horizon, and the same six signs of the zodiac will always be above and below the Earth.[34] Shadows there accordingly describe a circle, and make people "encircled with shadows," since in latitudes below the poles the heavens revolve just like millstones.[35] Shadowed unidirectionally are the temperate habitations, since whenever the Sun is in the south, people in the northern zone have shadows that slope toward the north, while those in our contratemperate zone have them sloping toward the south.[36] Shadowed bidirectionally will be those

31. On the equatorial ocean as excluded from Posidonius' geography see F118EK with Kidd *Comm.* 459–461.

32. "Inserted" *(hupoballesthai)* may have teleological implications linked to the geographical symmetry between terrestrial zones (on which see I.1 n. 66).

33. F210EK ends at line 131, but Theiler (F284) correctly includes lines 132–146 as a logical extension of lines 90–131. For its classification of zones see Strabo 2.5.37 and Ach. *Isag.* 66.28–67.6; also, cf. Ptol. *Alm.* 2.6, at 102.9, 107.14, and 114.23, and see I.6 n. 10.

34. See further lines 225–231 below.

35. See Figure 9(a).

36. See Figure 9(b).

below the equinoctial circle: for when the Sun leaves the equinoctial circle for the south (that is, the winter tropic), their shadows slope toward the north but when it travels to the summer tropic from the equinoctial circle, they would point toward the south.[37] That, then, is [Posidonius'] distinction between the zones of the Earth.

147: But what must also be realized here[38] is that while daytime lengthens and shortens over the same time period for everyone occupying our temperate zone, the addition and subtraction [of daytime] is still not equal at all [latitudes]. Instead, there is a major contrast between them, with some having a minimal addition and subtraction, others a very large one, and still others an intermediary one. This is caused by the heavens' not sloping equally at all [latitudes], and the north pole not being elevated [everywhere] an equal number of degrees from the horizon, but just minimally for anyone living in the south, more for anyone in the north, and an intermediary amount for anyone in between.

156:[39] To explain. Those traveling to the south from the north necessarily have the north pole at a lower elevation and the heavens with less of a slope, while the opposite holds for those going away from there to the north. That is because on the Earth [directly] below the equinoctial circle each of the poles, as we have said,[40] is observed on the horizon, and all the parallel circles have equal sections above and below the Earth. There the axis [of the cosmos] is also the diameter of the horizon, and there are no stars that are either always visible or always out of sight. But because of the spherical shape of the Earth, those who come toward us from the mid-torrid zone have our pole elevated, have altered horizons,

37. See Figure 9(c).

38. "Here" must refer to lines 1–89 above, the opening discussion of the lengths of daytimes. Lines 147–231 form in effect a supplement to lines 18–29 above, based on the scheme of terrestrial latitudes recapitulated from I.3.1–68.

39. Cf. I.3.6–12 and 15–18, where the situation at the equator is also taken as the point of reference. Only here (lines 161 and 164) is the axis of the cosmos (on which see Gem. *Isag.* 4.1) mentioned.

40. At I.3.9, 23–24 and 52–54.

and have the axis [of the cosmos] no longer as the diameter of any [horizon] because the slope that develops as the heavens are elevated above the plane depends on the elevation of the pole.

166:[41] There are also different arctic circles at different [northern] latitudes depending on alterations in horizons. This is because the arctic circles enclosing the stars that are always visible at each latitude must be described by the pole and the distance [from the pole] <at> each latitude's horizon.[42] So for people living near the mid-torrid zone (that is, south of us), the arctic circles are very small because the heavens slope minimally, and the [north] pole appears minimally elevated above the horizon. But for people in the north (that is, near the frigid zone) it is necessary that the arctic circles be very large, the pole have a significant elevation above the horizon, and the heavens consequently slope to an extreme degree. But for people right in between the north and the south (and this includes the Greeks and everyone at the same latitude),[43] all the [phenomena] just described occur to an intermediary degree.

179: Those parallel circles that are divided by the horizons at each latitude are, therefore, also divided equally in the mid-torrid zone, but unequally at the other latitudes. The larger and smaller sections above

41. Cf. with this paragraph I.3.32–35 and 44–68.

42. The idea behind "be described" *(graphesthai)* seems to be that, as the celestial sphere makes its daily rotation, the arctic circle is traced on the celestial sphere by the northernmost point of the horizon. The text that we have translated restores a deletion in Todd's edition and adds a supplement, so that at line 169 we now read *γράφεσθαι πόλῳ καὶ διαστήματι <πρὸς> τῷ παρ᾽ ἑκάστοις ὁρίζοντι*. That is, we take the distance between the pole and the horizon to be defined "at" the horizon, and for "at" we have supplied a preposition that defines locality much as it does in the standard phrases "in the north/south" (*πρὸς ἄρκτῳ/νότῳ*). In so emending we reject the possibility that the Greek as it stands can mean that the arctic circles are "drawn by the pole and the distance to the horizon" ("dessinés par le pôle et la distance à l'horizon," Goulet). That is the kind of meaning clearly needed by this text, and we have tried to elicit it with minimal intervention, though we concede that the solution may not be entirely satisfactory.

43. Given I.3.39–42 (cf. I.3 n. 9), this latitude would be 36°N.

and below the Earth will balance out at those latitudes, and in this way the lengthenings and shortenings of daytimes will also balance out proportionately.[44]

184: Those living adjacent to the mid-torrid zone do not have daytimes that significantly lengthen and shorten, since there the heavens slope minimally, and cause a slight variation in the division of parallel circles into unequal [sections] by the horizon. But people at the latitude adjacent to the frigid zone have an extreme variation in the lengthenings of daytimes and nighttimes, since there the heavens have an extreme slope, and also because the pole has a significant elevation above the horizon and for this reason makes the arctic circle there extremely large, resulting in its not being far distant from the summer tropic. The horizons at those latitudes consequently divide the parallel circles unequally in so extreme a disproportion that the lengthenings and shortenings of daytimes also involve an extreme variation.

197: For example, in Britain, when the Sun is in Cancer and causes the longest daytime, the daytime reportedly consists of 18 equinoctial hours and the nighttime of 6,[45] so that over this time interval there is light at this latitude during the nighttime, since the Sun runs alongside the horizon and sends out its rays over the Earth. (This of course also happens at our latitude, when the Sun approaches the horizon, since its light is well in advance of its rising.) So in Britain too there is light during the night, so that even reading becomes possible. In fact this is said to be absolutely necessary because, due to the section of the summer tropic below the Earth being minimal at this latitude, the Sun at this time effects its course alongside the horizon without going too far below the Earth.

44. On this "balancing out" *(summetria)* see lines 232–239 below. Over the course of a year each latitude will receive in principle (cf., however, I.1. n. 70 and n. 51 below) an equal amount of light and darkness.

45. See II.1.444. At Ptol. *Alm.* 2.6, 113.6–9 the parallel at 58°N ("through the southern part of Ireland") is assigned a longest daytime of 18 hours. For less precise data see Gem. *Isag.* 6.7–8, and Plin. *NH* 2.186.

208:[46] In the island called Thule (said to have been visited by Pytheas, the philosopher from Marseilles) the whole summer tropic is reportedly above the Earth, and in fact it becomes the arctic circle at that latitude.[47] When the Sun is in Cancer there, the daytime will last 1 month, if all the parts of Cancer are also always visible there; but if not, then to the extent that the Sun is present in the parts of that sign that are always visible.

213:[48] For those proceeding to the north from this island other parts of the zodiacal circle in addition to Cancer will become always visible in due proportion, and this means that as long as the Sun is going through those parts of the zodiacal circle that are [always] visible above the Earth at each latitude, it will be daytime.

218: And necessarily there exist latitudes of the Earth where the daytime is 2 and 3 months long, and 4 and 5 months, too.[49] Also,[50] since directly under the pole there are 6 signs of the zodiac above the Earth, then as long as the Sun is going through these signs, which are always visible, it will be daytime, since here the same circle is the horizon, the arctic circle, and the equinoctial circle. That is, people at Thule have the summer tropic coinciding with the arctic circle, but people still further north have the arctic circle exceeding the summer tropic relative to the parts [of the heavens] leading to the equinoctial circle, and this occurs proportionately. But for those directly under the pole the equinoctial cir-

46. At Ptol. *Alm.* 2.6, 114.9–11 Thule, an island north of Britain, perhaps identifiable with Iceland or part of Scandinavia, is assigned a latitude of 63°N, with a longest daytime of 20 hours. The latitude at which the longest daytime is a month is 67°N (Ptol. *Alm.* 2.6, 115.8–16). For the claim by Pytheas (probably late fourth century B.C.) that the arctic circle and summer tropic coincide at Thule see Strabo 2.5.8, Kidd *Comm.* 745–746, and Roseman (1994) 104–109, who translates and discusses Cleomedes' report (lines 208–210 = Pytheas T27 Roseman) and its context.

47. See Figure 10(a).

48. Cf. with lines 213–219 Ptol. *Alm.* 2.6, 115.8–116.20.

49. See Figure 10(b).

50. Cf. with lines 219–231 Ptol. *Alm.* 2.6, 116.21–117.9.

cle assumes all three relations: it is the arctic circle because it encloses the stars that are always visible, since at this [latitude] absolutely no star sets or rises; it is the horizon because it separates the hemisphere of the heavens that is above the Earth from the one below the Earth; and it is the equinoctial circle because it alone divides daytime and nighttime equally at that latitude, and while everywhere else too it is the equinoctial circle to an equivalent degree, it is no longer either a horizon or an arctic circle.

232: These, then, are the variations in the lengthenings and shortenings of nighttimes and daytimes, although the darkenings and illuminations of the air are made equal at all latitudes. In the mid-torrid zone, that is, nighttimes are always equal to daytimes, but at the other latitudes this kind of equalization is achieved differently: that is, the longest daytimes at each latitude are made equal to the longest nighttimes,[51] and neither the darkenings nor illuminations of the air exceed one another, but the year as a whole divides them equally.

239: The cause of the whole variation in the cases just described is the Earth's shape, which is spherical, as a fortiori is the whole cosmos itself. In other words, none of the [phenomena] just described could occur with other kinds of shapes. We shall demonstrate next that both the whole cosmos, and its most significant parts, do have this shape.[52]

51. Since atmospheric conditions make the longest daytime longer than the longest nighttime (see I.1 n. 70), this assumption of exact symmetry does not in fact hold true.

52. The Earth's sphericity had previously been assumed; see I.1.224, 245–246, I.3.2–3, and I.4.163.

CHAPTER FIVE

1: Now sight alone seems to suggest that the cosmos is a sphere,[1] but *that* must not be made a criterion for its shape, since everything does not in fact usually appear to us as it [really] is.[2] It follows that it is on the basis of what is "clearer" (that is, what is presented cognitively to us)[3] that, in accord with what is patently implied,[4] we should aim to arrive at things

1. Cf. I.1.176–191, where cosmic sphericity was demonstrated on the basis of "what is presented in perception," or, as here, "sight" *(opsis)*.

2. On the Stoic concept of the criterion of truth, and the methodology summarized in this opening paragraph, see also the Introduction.

3. The terminology in the phrase *apo tōn enargesterōn kai kataleptikōs hēmin phainomenōn* is used elsewhere by Posidonius; see T83.2, F159.2 and F169.45 EK, and cf. Kidd *Comm.* 74 who rightly calls it a "criterion." The words *katalēptikōs phainomena* that gloss "clearer" also embody the technical Stoic term for a cognitively reliable sense presentation, the *kataleptikē phantasia* (see Introduction with n. 29).

4. This translates *kata tēn phainomenēn akolouthian*, a phrase difficult to interpret without a context for its use. Presumably the implication *(akolouthia)* is "apparent" (the literal meaning of *phainomenē*) because human reason recognizes it as clear or evident, and our translation "patently" is designed to reflect this through alternative language. Thus at lines 126–138 below (which are anticipated at lines 6–9 here) there are two inferences (or "transitions"; cf. *metiontes*, line 8)

that are not in and of themselves fully displayed. Accordingly, if we demonstrate that the most solid (that is, the most compact) part of the cosmos, the Earth, has a spherical shape, we could easily learn by a transition from this to its remaining parts that they are all spherical, and in this way that the whole cosmos too has this sort of shape.[5]

10: There have been numerous differences among earlier natural philosophers about the shape of the Earth: some, by following only the sense presentation based on sight, claimed that its shape was flat (i.e., a plane);[6] others, who supposed that water would not be stationary on an Earth that did not have a "deep" (i.e., concave) shape, said that it had just that shape;[7] others claimed that the Earth was shaped like a cube (i.e., square); others that it was shaped like a pyramid.[8] Our school, as well as

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from the sphericity of the Earth to that of the air and aether (and thus the whole cosmos), and these are grasped via physical theory and its geometrical manifestations. In the main body of this chapter too (lines 20–113) implications are grasped as "evident" within more restricted contexts in the arguments for the Earth's sphericity, and so the phrase *kata tēn phainomenēn akolouthian*, despite its use here in connection with the larger cosmological picture, has completely general application.

5. The structure of the cosmos is itself unobservable, that is, it is one of the things "not in and of themselves fully displayed" *(mē autothen ekphanē)*. It is displayed to the extent that we can see the air and aether, but their sphericity can only be inferred with the help of physical theory (see lines 128–134 below); it cannot be inferred from the phenomena alone, as can the sphericity of the Earth (see lines 104–113 below).

6. While the flat-Earth cosmology is associated with Homer and early Greek thought (e.g., by Gem. *Isag.* 16.28), the present text may apply to the Epicureans (on whom see Furley [1996]), who at II.1.2–5 are similarly described as having inferred the Sun's size from its "visual sense presentation"; see also II.1. n. 101.

7. Democritus (DK 68A94) thought that there was a central hollow on a flat and oblong Earth.

8. For other shapes see Ptol. *Alm.* 1.4, 15.23–16.7 for the cylinder, and Theon *Expos.* 120.23–121.1 and Eucl. *Phaen.* 4.26–6.14 for the cone and cylinder. See also the Epicurean polemic at Cic. *De nat. deor.* 1.24.

all the scientists and most of the Socratic school, affirmed that the shape of the Earth was spherical.[9]

20: Now since no other shape beyond those mentioned could be appropriately attached to the Earth, the following disjunction would be necessarily true: *the Earth is either flat (i.e., a plane), or concave ("deep"), or square, or pyramidal, or spherical in shape.* So having posited this disjunction as true, then by going forward on the basis of what the logicians call "the fifth undemonstrated [argument constructed] through multiple [disjuncts],"[10] we shall demonstrate that the Earth has a spherical shape. That is, we shall state, as indeed we shall demonstrate, that *the Earth is neither flat, nor concave, nor square, nor pyramidal.* We shall then conclude that *it is absolutely necessary that the Earth be spherical.*

30: That the Earth is not a plane we may learn from the [following arguments]. *(a)* If it were flat (i.e., a plane) in shape, then there would be a single horizon for all peoples: for it is inconceivable how, if the Earth had such a shape, horizons would alter. And given a single horizon, the Sun's risings and settings, and thus also the beginnings of daytimes and nighttimes, would occur at the same time everywhere. But this does not in fact happen; instead, in terrestrial regions the variation in the [phenomena] cited is clearly very considerable, in that the Sun sets and rises at different times at different places. For example, the Persians who live in the east are said to encounter the onset of the Sun 4 hours earlier than the Iberians who live in the west.[11] This [variation] is also proven

9. For the Stoics ("our school"; cf. Posid. T85EK) see *SVF* 2.648 and Posid. F18.20 and F49.6–7 EK; for Plato see *Phaedo* 108e4–109a6 (with Furley [1989b] 23–26). The "scientists" *(hoi apo tōn mathēmatōn)* include, but are not restricted to, mathematical astronomers (see II.6.122).

10. On this argument see *SVF* 2.241 (80.17–20) and 2.245 (82.34–83.3), and Sext. Emp. *PH* 2.158. It has the form "either p or q or r," "not p and not q," "therefore r." The way that "not p" and "not r" are demonstrated in this chapter is via the Stoics' "second undemonstrated argument" (e.g., *SVF* 2.242, p. 81.1–12), their equivalent of *modus tollens;* see n. 28 below.

11. For the Iberians as the westernmost inhabitants of the known world see lines 42–43 and 78 below, and II.1.459–461; also Strabo 1.4.5 and Aujac (1966)

from other [phenomena] but particularly from the eclipses of the heavenly bodies, which, though they are eclipsed everywhere over the same time period, are still not detected at the same hour. Instead, the [heavenly body] that is eclipsed among the Iberians in the 1st hour is detected as undergoing an eclipse among the Persians in the 5th hour, and proportionately elsewhere.[12] *(b)* If the Earth's shape were flat, the pole would be seen by everyone at an equal distance from the horizon, as would the same arctic circle. Nothing like this is present in the phenomena; instead, the elevation of the [north] pole is seen as very small for the inhabitants of Syene and for the Ethiopians, yet as very great among the Britons, and proportionately at intervening latitudes.[13] *(c)* For someone leaving for the north from the south some of the stars that are seen in the south are concealed, and others previously out of sight come to be seen in the north, and the opposite happens to anyone who

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184. Strabo 1.4.5 and others usually cite India rather than Persia as the easternmost location.

12. The sphericity of the Earth is best demonstrated from the observation of lunar eclipses at different times and locations; see Ptol. *Alm.* 1.4, 15.12–13 and Theon *Expos.* 121.5–12. Plin. *NH* 2.180 uses both lunar and solar eclipses in his argument for the Earth's sphericity, but because of lunar parallax, a solar eclipse will differ for different observers "at the same hour," and in some cases will not be seen at all. It is unusual in antiquity to find comparisons of the Sun's rising times at different longitudes. It is worth noting that Cleomedes' estimate of a 4–hour difference between Persia and Iberia (Spain) may be based on reports of a lunar eclipse that was observed simultaneously at Arbela on Sept. 20, 331 B.C., during Alexander's campaign and at Carthage. Ptolemy (*Geog.* 1.4) says that the eclipse occurred in the 5th hour (of night) at Arbela and in the 2nd hour at Carthage, which would make the difference between times of sunrise there roughly 3 hours (though it should only be about 2¼ hours). Pliny's report (*NH* 2.180), which is better so far as it goes, maintains that the eclipse took place in the 2nd hour at Arbela, but says only that it was seen at the same time that the Moon rose (that is, at sunset) in Sicily. See Neugebauer (1975) 667–668 and 938.

13. Syene is at the latitude of the northern tropic (I.4.93, and lines 59–60 below), while the Ethiopians are probably at the latitude of Meroe, the southernmost latitude identified in lists of latitudes; see II.1.440–441.

might go south from the north.[14] None of this would happen if the Earth had a flat shape that caused a single horizon. Therefore the Earth does not have this shape. *(d)* Daytimes would also turn out to be of equal length for everyone,[15] although entirely the opposite is present in the phenomena.

57: *(e)* Indeed, if the Earth had a shape that was flat (i.e., a plane), the whole diameter of the *cosmos* would be 100,000 stades![16] Look.[17] *(1)* People at Lysimachia have the head of Draco overhead, while Cancer is located above the area of Syene. *(2)* The "arc [of the meridian]" between Draco and Cancer is $\frac{1}{15}$ of the "meridian" passing through Lysimachia and Syene (as is demonstrated by sundials). [*(3)* Syene is 20,000 stades from Lysimachia.][18] *(4)* $\frac{1}{15}$ of the whole "circle" is $\frac{1}{5}$ of the "diameter."[19]

14. At I.3.12–43 the sphericity of the Earth was identified as the cause of these variations.

15. This is a consequence of there being a single horizon; see lines 30–39 above.

16. This argument concerns the size of the *cosmos*, not the Earth (see Goulet 200 n. 162 against Neugebauer [1975] 961–962 plus fig. 97 at 1406), and must originally have been a *reductio ad absurdum* that invoked a bizarre cosmology (familiar to Ptolemy; see *Alm.* 1.3, 11.14–24 and cf. n. 21 below) in which a flat Earth has the heavens parallel to it, rather than encircling it. This is the structure implied by assumptions *(3)* and *(4)* below; i.e., if $\frac{1}{15}$ of the flat Earth's extent is 20,000 stades, its total extent is 300,000 stades, or the same as that of the heavens, which must therefore be parallel to it. Hence "arc," "meridian," "diameter," and "circle" need to be used in quotation marks in this passage to reflect their etiolated meaning when applied to such a nonspherical cosmology. However, by having the flat Earth surrounded by a sphere in this argument (see n. 21 below), Cleomedes, or his source, has misrepresented this reasoning. Hence the figures in this passage should be used with caution in historical or geographical reconstructions; for attempts at these see, for example, Neugebauer (1941), Collinder (1964), and Goulet 200 n. 162.

17. What follows is a "procedure" (*ephodos;* see Introduction n. 38), with four overt assumptions and an implicit axiomatic principle (see n. 22 below).

18. This is to anticipate the information given at line 68 below.

19. This is because the diameter of a circle is taken to be a third of the circumference, as at I.7.118–120, and II.1.299–300 and 321–322.

63: So if, by hypothesizing that the Earth is a plane,[20] we produce perpendiculars to it from the extremities of the "arc" extending from Draco to Cancer, they will [by *(1)*] touch the "diameter" [of the Earth] that measures the "meridian" through Syene and Lysimachia.[21] Thus the distance between the two perpendiculars will be 20,000 stades, since [by *(3)*] there are 20,000 stades between Syene and Lysimachia. So since [by *(2)* and *(4)*] this distance is ⅕ of the whole "diameter," the whole "diameter" of the "meridian" will be 100,000 stades. So if the cosmos has a "diameter" of 100,000 stades, it will have a "great circle" of 300,000 stades[22]—in relation to which the Earth, although a point [in relation to the cosmos], is 250,000 stades [in circumference], while the Sun is much larger than this, although it constitutes a minimal part of the heavens.[23]

20. In the calculations of the size of the Earth or the Sun in I.7 and II.1, the sphericity of the Earth and the cosmos are, of course, implicitly assumed.

21. See Figure 11. In order to reflect the misleading reasoning in this passage (see n. 16 above), the shapes of the flat Earth and flat heavens in this figure are finite and circular. They should be indefinite in shape and extent. As Ptolemy, *Alm.* 1.3, 11.14–24, argues, if *both* the Earth *and* the heavens are flat, the heavenly bodies will move in a straight line "to infinity," with no plausible explanation available for their rising and setting, or for their rectilinear motion ever being reversed. Thus the problem that Cleomedes should be posing a flat-Earther is that the cosmos is infinite, rather than, as is concluded here, minuscule.

22. The calculation is implicitly based on the axiom that two quantities have the same ratio to one another as the equimultiples of these quanta taken in corresponding order (cf. Eucl. *El.* 5 prop. 15). Thus if d is the diameter of a circle, and c is its circumference, then $d{:}c :: 1{:}3 :: 5 \times 20{,}000{:}15 \times 20{,}000$. The subsequent calculations of the circumference of the Earth, and the size of the Sun, also rely on this axiom (see I.7 nn. 9 and 21; II.1 nn. 58 and 73), which is known to have interested Posidonius (see I.7 n. 9). Perhaps the present argument, more appropriately articulated (see previous note), was originally Posidonius' *reductio ad absurdum* of the theory of a flat Earth.

23. The comment following the dash may be Cleomedes' insertion, since if he, rather than any source, is responsible for misunderstanding the cosmological assumptions of this argument (see n. 21 above), he could now be drawing on Eratosthenes' calculation of the size of the spherical Earth (I.7.109–110), and alluding to the later calculation of the size of the Sun (cf. II.1.324–325).

Surely it is obvious from this [argument] too that the Earth cannot be a plane?

76: That the Earth also does not have a "deep" (i.e., concave) shape may be seen from the following [arguments]. *(a)*[24] If its shape were like this, daytime would begin for the Iberians before the Persians, since the protrusion [of one side] of the Earth would obstruct [the Persians] who are close to it, without impeding the line of sight for [the Iberians] who are at a greater distance away. After all, when any hollow object is out in the Sun, the part of it on the Sun's side is in a shadow when the Sun rises, whereas the part directly opposite is illuminated.[25] So if the Earth's shape were concave, the outcome would be same throughout the whole world too: that is, people in the west would encounter sunrises earlier. But in fact the opposite is present in the phenomena. *(b)* Also, if the Earth had this sort of shape, then for people in the south, the north pole would be visible at a significant distance above the horizon, while it would be obstructed for people in the north by the protrusion [of the side of the Earth closest to them]. And by the same token, given this shape, more stars would always appear visible to people in the south, and consequently their arctic circle would be larger. Entirely the opposite to this is present in the phenomena. *(c)* Those living in the deepest part of the concavity would be unable to see the six zodiacal signs above the Earth, and thus not even half of the equinoctial circle. For example, when we descend to a deeper place and look back toward the heavens, we see a small part of it, not the whole hemisphere.[26] *(d)* Nighttimes would also always exceed daytimes, since the arc of the heavens located below the convex part [of the Earth] would far exceed the

24. Ptol. *Alm.* 1.4, 15.16–17 briefly notes this argument.

25. This use of any hollow object to illustrate the consequences of the Earth being hollow is in line with Stoic accounts of concept formation "by analogy"; see, for example, *SVF* 2.87 (with a parallel at 29.15–16).

26. As at I.8.130–132, valleys rather than subterranean locations (cf. II.1.38–44) must be intended here.

arc located above the concave part, assuming that the Earth is at the exact center of the cosmos.

98: If the Earth were cuboid (i.e., square), the result would be a daytime consisting of 6 hours and a nighttime of 18, given that each side of the cube would be illuminated for 6 hours. But if the Earth were like a pyramid too, each side of it would be illuminated for 8 hours.[27]

102: So if the phenomena demonstrate that the Earth has none of these shapes, it is necessarily spherical in accordance with the fifth [undemonstrated argument] from multiple [disjuncts]. But it can also be demonstrated directly that the Earth is spherical by starting out in the same way from the phenomena, given that precisely the same [phenomena] that demonstrated that the Earth had none of the [non-spherical] shapes listed above demonstrate that it is spherical.[28] That is, horizons on the Earth alter, and the following are not observed as being identical everywhere: the stars in the north and the south, the elevation of the pole, the size of the arctic circle, and the lengths of nighttimes and daytimes. All these phenomena clearly demonstrate that the shape of the Earth is spherical. For it is impossible for any of them to occur with a different shape,[29] but it is possible for properties of this kind to be displayed only in association with a sphere.

114: Also,[30] when at sea we are about to approach land, our line of

27. Ptol. *Alm.* 1.4, 15.19–23 also mentions a triangular and square shape, and notes that they would be subject to the arguments against the Earth's having any polygonal shape.

28. The reasoning at lines 30–101 has been "indirect." That is, if "p entails q" is the direct argument (i.e., given phenomena entail that the Earth is spherical), then previously the argument form was "not-q entails not-p; but p; therefore, not not-q," i.e., *modus tollens* (see n. 10 above). In other words, nonspherical shapes are eliminated because they entail impossible phenomena.

29. For these arguments used to eliminate nonspherical shapes see lines 30–39, 44–49, and 54–56 above, and cf. I.4.239–242.

30. This is an elementary application of the argument from changing horizons at lines 30–39 above. Cf. I.1.183–190 where it is used in a slightly different form as a preliminary proof of the sphericity of the cosmos.

sight first encounters mountain peaks, while everything else is obstructed by the Earth's curvature.[31] Next, as we go over the curvatures, we encounter in the course of the journey the sides and spurs of mountains. And within the boats themselves, when we ascend the mast and get above the obstructing curvatures, we invariably see those parts of the land that are invisible from the decks and the hold. Also, when a ship leaves land, the hulls disappear first, although the masts are still visible; but when it approaches land from the sea, then, by the same token, the masts are seen first, while the hulls are still obstructed by the curvature of the water. All these [phenomena] indicate through virtually geometrical demonstrations that the shape of the Earth is spherical.[32]

126: It is necessary, then, that the air enclosing the Earth also be a sphere, since exhalations from the whole of the Earth rise and flow together, and thus fashion the same shape for the air too.[33] (Solid bodies can also, of course, have numerous configurations, but in the case of a substance that is composed of pneuma or of fire,[34] wherever [such types of matter] exist independently, nothing like this can happen. This is because they reach the shape proper to their nature by being "tensionized," that is, by being stretched equally in all directions from the exact center [of the Earth], since their substance is malleable, meaning that nothing

31. If the Earth has a "curvature" (*kurtōma;* here and at lines 118, 120, and 124 above), then, since curvatures define sphericity (cf. I.1.247 and 250), this argument contains a *petitio principii.* Ptol. *Alm.* 1.4, 16.13–18 argues more carefully that the surface of the sea causes the land to appear to "rise up" as we approach it. For other versions see Plin. *NH* 2.164, Strabo 1.1.20 (= Posid. 3b Theiler), and Theon *Expos.* 122.17–123.4.

32. Cf. also I.8.17–18 on geometrization.

33. On terrestrial exhalations cf. *SVF* 2.527 (168.25–26), and see I.8.79–88. The argument from here to line 138 was outlined at lines 6–9 above; see notes 4 and 5 above.

34. Pneuma is a compound of air and fire (e.g., *SVF* 2.442), and so the two elements identified here, the air and the aether, can also form a realm of matter describable as "composed of pneuma or fire," since they represent pneuma in its purest form, unaffected by solid matter.

solid exists which would configure them differently.[35]) Since the air is spherical, so too is the aether, since [the aether], being in turn able to enclose the air,[36] and neither being bent into angles by anything solid, nor having anything forcing it into some shape with uneven lengths,[37] is itself necessarily a sphere. So it is absolutely necessary that the whole cosmos too have such a shape.[38]

139: It is also entirely plausible that the most complete of bodies has the most complete of shapes. And the cosmos is the most complete of all bodies, while the sphere is the most complete of all shapes. For the sphere can enclose every shape that has the same diameter as it, but no other shape can enclose a sphere that has a diameter equal to it.[39] So it is absolutely necessary that the cosmos be a sphere.

35. Pneuma holds the Stoic cosmos together by "tensional motion" (see I.1.72–73). Hence non-solid matter is next said to have a sphericity that results from being "tensionized" *(tonousthai)*, i.e., from the oscillation of pneuma from the center to the periphery of the cosmos and back to produce a "stretching effect" (the literal meaning of *tonos*).

36. Ptol. *Alm.* 1.3, 13.21–14.16 argues that the aether (for him immutable) is spherical just because of its homogeneity, and because it is occupied by observably spherical bodies.

37. See I.1.166–168 for the contrast between sphericity and shapes with uneven lengths.

38. See also *SVF* 2.547 and 681, and Posid. F8EK, for this conclusion. Although the present argument emphasizes the relative density of the elements, and the capacity of the lighter ones for pneumatic, or tensional, motion, it need not conflict with the earlier principle (I.1.94–95, 173–174, and 191–192), that all the elements are centripetal. Furley (1993) defends such a system of dynamics. Wolff (1988) 497–533 and 539–542, however, suggests that the lighter bodies push the heavier ones to the center and move around them in a vortex-like motion.

39. For this claim see Pl. *Tim.* 33b1–7, Arist. *De caelo* 286b25–33, Cic. *De nat. deor.* 2.47, *SVF* 2.1009 (299.15–19), and cf. Ptol. *Alm.* 1.3, 13.14–20. Cleomedes' version holds for the five regular solids; see Eucl. *El.* 13 props. 13–18.

CHAPTER SIX[1]

1: We shall establish that the Earth occupies the exact center of the cosmos, by which it is enclosed, by again[2] starting out from the procedure based on the fifth undemonstrated [argument constructed] through multiple [disjuncts]. The following disjunction, that is, is necessarily true: *The Earth, which is encompassed by the cosmos, is either in its east, or its west, or its north, or its south, or higher than its center or lower—or it occupies its exact center.* But, as we shall demonstrate, *none of the [propositions] prior to the last is true.* Therefore, *it is necessary that the Earth occupy the center of the cosmos.*

9:[3] That it is not in the east is clear from the following. *(a)* If it were in the east, then shadows from objects illuminated at sunrise would be

1. This whole chapter can be compared with Ptol. *Alm.* 1.5, which is diagrammatically analyzed at Pedersen (1974) 39–42. The arguments here also assume the thesis of I.8, that the radius of the Earth is negligible in relation to the distance from the Earth to the Sun, or to the edge of the cosmos, i.e., that the observer is effectively at the center of the Earth. The theses of I.6 and I.8 are thus conventionally linked; see Eucl. *Phaen.* prop. 1 (10.11–12), Gem. *Isag.* 16.29, and Theon *Expos.* 120.11–12.

2. See I.5.23–26.

3. At Ptol. *Alm.* 1.5, 17.4–5 such displacement is described as a case of the Earth's not being on the axis of the cosmos, but still equidistant from both poles.

shorter, but at sunset these would be sent out farther; that is because when objects that give out light are nearby, shadows [cast by them] are shorter, but when they are more distant, shadows are invariably enlarged in proportion to the distance.[4] *(b)* If we were closer to the east, all the [heavenly bodies] would appear larger to us as they rise, while on setting (that is, as they continually went farther away), they would appear smaller.[5] *(c)* The first six hours of the daytime would also be very short, since the Sun would reach the zenith rapidly, whereas those hours after the sixth would be lengthened, given the greater distance from the zenith to the west.[6] None of these [observations] is present among the phenomena. Therefore the Earth is not farther east. Yet by the same token neither is it farther to the west; otherwise all the [observations] would as a result be the opposite to those just described.

22:[7] But if the Earth were farther north, then whenever the Sun rises, shadows from objects illuminated by it would as a result extend in the direction of that region. And if it were in the south, shadows would also slope southwards, both when the Sun rises and when it sets. In fact none of this occurs, but at the equinoxes, when [the Sun] rises, shadows slope toward where it sets at the equinoctial setting [point], and when it sets, they slope toward where it rises at the equinoctial rising [point]. But at

4. The longer shadows will, given *(c)* below, also be cast for a longer period of the daytime.

5. Cf. Ptol. *Alm.* 1.5, 18.5–8, and in the *Caelestia* cf. I.8.32–37.

6. Ptol. *Alm.* 1.5, 17.9–18.4 notes only the elimination of the equinox, here left implied.

7. Ptol. *Alm.* 1.5, 18.12–19.8 describes this as a case of the Earth's being on the axis of the cosmos but displaced toward one of the poles. He rejects it by using the same evidence of the altered visibility of zodiacal signs used here at lines 33–35 against the Earth's being "higher" or "lower" than its central position. The latter cases are identical with the present case of displacement toward one of the poles, and this seems to be acknowledged in the summary at line 40 below when only "four regions" of displacement are noted. The six catalogued in this chapter were perhaps intended to correspond to the six noncentral directions identified at I.1.150–158.

winter solstices when [the Sun] rises, [shadows slope] toward where it sets at the summer solstitial setting point, and when it sets, [they slope] toward where it rises at the summer solstitial rising [point]. But when, <on going> back <up>[8] from the south, it rises [at summer solstices],[9] shadows slope toward where it sets at the winter solstitial setting [point], but when it sets, they slope toward where it rises at the winter solstitial rising [point]. Thus [over the course of a year] the shadows form a chiasmus.[10] Therefore the Earth is not in any of these regions.

33: If the Earth were higher than the center, then the half of the heavens above the Earth would not be visible, nor would the six zodiacal signs (i.e., 180 degrees), nor half of the equinoctial circle, but less than all these [would be visible].[11] Hence nighttimes too would as a result always be longer than daytimes. But if the Earth were lower than the center, the result would be the complete opposite to what has just been described, since the hemisphere above the Earth would be larger.[12] [This does not happen.] Therefore the Earth is at neither a higher, nor a lower, position.

8. This supplement translates ἀνατρέχων, proposed for a lacuna in *Caelestia* ed. Todd, apparatus criticus at 1.6.29. A verb is needed here to complement ἐνθένδε ("thence," i.e., back again from the south).

9. This gloss is needed to balance "at winter solstices" (line 28), and is implied by "back up."

10. This chiasmus, or "decussation," involves two diagonals for the solstitial shadows; see Figure 12. The illustration could be Posidonian, given that at I.4.132–146 (cf. Figure 9) zones are defined in terms of shadows in a passage that can be attributed to him; see I.4 n. 33.

11. Throughout this paragraph the observer is assumed to be at ground level. On the special conditions under which less than 180 degrees are seen in this position from a centrally located Earth see I.8.127–132 and I.8 n. 33.

12. More than 180° would be visible from a centrally located Earth if the Earth were large enough, or the cosmos sufficiently small; see I.8.134–139 and I.8 n. 34, and II.6.122–138 and II.6 n.16. Also, under normal conditions, the refraction of light by the air at the horizon enables any terrestrial observer to see slightly more than half of the celestial sphere at any time.

40: It has been demonstrated that the Earth is not in any of the four regions [mentioned above].[13] Therefore it is necessary that it occupy the exact center of the cosmos. (In addition, the Earth is the heaviest of the bodies in the cosmos, and so must occupy the [place] farthest downwards, which [in a sphere] is also identical with the exact center.)[14]

13. See n. 7 above.

14. This refers to the centripetal motion of the elements (the demonstration of which was postponed at I.1.94–95, 173–174, and 191–192; see Introduction n. 6), which will establish that the Earth is stable at the center of a spherical and stable cosmos, and so rule out saving the phenomena introduced in this chapter (like many of those in I.5 and I.8) by a different cosmological arrangement (see Introd. n. 23). Ptol. *Alm.* 1.5–6 (his equivalents to *Caelestia* I.6 and I.8) are immediately followed by a demonstration (1.7) that the Earth is immobile by a physical theory broadly similar to the Stoic theory of centripetal motion; see Wolff (1988) 498–502.

CHAPTER SEVEN

1: Natural philosophers have held numerous doctrines about the size of the Earth, but two of these are superior to the rest. Eratosthenes' doctrine demonstrates its size by a geodesic procedure,[1] while Posidonius' is less complicated. Each [philosopher] takes certain assumptions [as being the case], and then arrives at demonstrations via the implications of the assumptions. The first [doctrine] that we shall discuss is Posidonius'.[2]

7: He states that *(P1)* Rhodes and Alexandria are located below the same meridian.[3] *(Def. 1)* Meridians are the circles drawn through the poles of the cosmos, and through a point that lies at the zenith of each of those

1. Our translation reflects Gratwick (1995) 178 n. 1. While the procedure here is called *geōmetrikos,* that term cannot mean "geometrical," since Posidonius as well as Eratosthenes (ca. 276–194 B.C.) employs geometry.

2. For literature on this calculation see Kidd *Comm.* 728–729; add Taisbak (1973–74) and Gratwick (1995). See also Figure 13. In this calculation and that of Eratosthenes below the unit of measurement used is the stade. Since it was never standardized, its value is difficult to determine from the ancient sources, and it cannot be readily translated into modern values for comparative purposes. For further discussion see Lloyd (1987) 233–234, and the literature cited at González (2000) 216–217.

3. This was the standard view (Ptol. *Alm.* 5.3, 364.9–10 and Strabo 2.5.7; cf. Toomer [1984] 255 n. 16), although Rhodes is in fact 1°50' west of Alexandria.

[observers] who stands on the Earth. (Thus, while the poles are the same for everybody, the point at the zenith is different for different [observers], which is why infinitely numerous meridians can be drawn.) Rhodes and Alexandria, then, are located below the same meridian, and *(P2)* the distance between the cities is held to be 5,000 stades.[4] Let it be assumed that this is so. *(Def. 2)* All the meridians are also included among the great circles in the cosmos, since they divide it into 2 equal parts by being drawn through its poles.[5]

18: Now with this assumed to be the case, Posidonius next *(P3)* divides the zodiacal circle (which, since it too divides the cosmos into 2 equal parts, is [by *def. 2*] equal to the meridians) into 48 parts by dividing each of its *dōdekatēmoria*[6] into quarters. Now if the meridian through Rhodes and Alexandria is also divided into the same 48 parts as the zodiacal circle, then its sections will be equal to the sections of the zodiacal circle just identified. The reason is that *(def. 3)* when [2] equal magnitudes are divided into equal [parts], their parts must also be equal to the parts of what has been divided.[7]

4. "Is held" (δοκεῖ) (14–15; also line 43 below) here implies "generally believed on good authority"; cf. I.2.26–27 and II.3.18 for this sense, and I.4.197–199, II.1.441, II.3.10, and II.7.1 for figures cited on external authority, without reservations. Kidd *Comm.* 726, however, calls the number given in *(P2)* "hypothetical," and claims that the whole Posidonian calculation reported here is designed to illustrate "the hypothetical method rather than the accuracy or certainty of the figures." But even though Posidonius uses a method of calculation that can be identified independently of the numbers used (see n. 9 below), that does not make the numbers cited "hypothetical." There is a significant difference between using numbers that have some reasonable credibility, and arbitrarily (or hypothetically) stipulating numbers to facilitate a calculation (as at II.1.274–275 in Posidonius' measurement of the size of the Sun). The number in *(P2)* is clearly of the former kind. See also n. 11 below.

5. On the definition of great circles see I.3.56–62.

6. On this term see I.4 n. 17.

7. Compare Eucl. *El.* 1, *Not. comm.* 3 (5.11–12): if equals are subtracted from equals, the remainders are equals.

27: Now with [*(P1)*–*(P3)*] assumed to be the case, Posidonius next says that the star called Canobus, which is located in the south at the rudder of Argo, is very bright.[8] (This star is not seen at all in Greece; that is why Aratus does not mention it in his *Phaenomena*.) But for people going to the south from the north, the star starts to be seen at Rhodes, and once seen on the horizon immediately sets along with the revolution of the heavens. But when we reach Alexandria by sailing the 5,000 stades from Rhodes, this star, when precisely at the meridian, is determined as being elevated above the horizon $\frac{1}{4}$ of a zodiacal sign, that is, [by *(P1)* and *(P3)*] $\frac{1}{48}$ of the meridian through Rhodes and Alexandria.

38: Now it is necessary [by *(P1)* and *(P3)*] that the section of the same meridian located above the distance separating Rhodes and Alexandria also be $\frac{1}{48}$ of that meridian, because the Rhodians' horizon is also distant by $\frac{1}{48}$ of the zodiacal circle from that of the Alexandrians.[9] So since [by *(P2)*] the portion of the Earth located below this section is held to be 5,000 stades, the portions located below the other sections also consist of 5,000 stades. And in this way the circumference of the Earth is determined as 240,000 stades[10]—*if* [by *(P2)*] there are 5,000 stades between

8. On Canobus (sometimes spelt Canopus) (α Carinae), the brightest star after Sirius, see Aujac (1975) 132 n. 6 (on Gem. *Isag.* 3.15), and Kidd *Comm.* 725–726.

9. In Figure 13, since RV is parallel to AW, angle APV = α (Eucl. *El.* 1 prop. 29). Since triangle APV is similar to triangle RTV, angle RTA = angle APV = α. The three ratios that are identical in this calculation (cf. I.5 n. 22) are 1:48 :: $\frac{1}{4}$ *dōdekatēmorion*:full circle :: 5,000:240,000 stades (on the numbers in the latter see n. 4 above). Since the same basic principle or axiom underlies Eratosthenes' calculation (n. 21 below), Posidonius could be the source for both reports in this chapter. He was certainly interested in relations between ratios; see Galen *Inst. log.* 18 (cf. F191.13–15 EK), and on the axiomatization of such relations, see Hankinson (1994) 73–74.

10. Strabo 2.2.2 reports "about *(peri)* 180,000 stades," i.e., 500 stades per degree of the circumference. This implies a distance of 3,750 stades between Rhodes and Alexandria, the figure that Strabo 2.5.24 says that Eratosthenes calculated by the use of sundials.

Rhodes and Alexandria. Otherwise, [it will be determined] in proportion to the [true] distance.[11] That, then, is Posidonius' procedure for dealing with the size of the Earth.

49: Eratosthenes' [calculation], by contrast, involves a geodesic procedure, and is considered to possess a greater degree of obscurity.[12] But the following [assumptions], when stated by us as presuppositions, will clarify his account.

51: Let us first assume here too [cf. *(P1)*] that *(E1)* Syene and Alexandria are located below the same meridian; [second] that *(E2)* the distance between the two cities is 5,000 stades.[13] Third, [assume] that *(E3)* the rays sent down from different parts of the Sun to different parts of the Earth are parallel, as geometers assume to be the case.[14] Fourth, let the following assumption demonstrated by geometers be made: that *(E4)* straight lines intersecting with parallel lines make the alternate angles equal.[15] Fifth, [assume] that *(E5)* the arcs [of a circle] standing on equal angles are similar, that is, have the same proportion (namely, the same

11. The gloss "true" is justified here, since the figure of 5,000 stades is only "held" (i.e., widely believed) to be true (see lines 14–15 and 43). Kidd *Comm.* 726–727 again (cf. n. 4 above) sees the *caveat* in line 46 as evidence of Posidonius' use of "hypothetical method." But aside from an uncertainty as to whether this caveat was entered by Posidonius or Cleomedes, for Posidonius to admit quantitative corrigibility (cf. also I.4.208–213 and II.3.40) would scarcely show that he "was not primarily interested in figures or in accuracy" (Kidd *Comm.* 727). In fact, since the same basic principle or axiom underlies the two calculations reported in this chapter (see n. 21 below), it is even conceivable that Posidonius was the source for both of them.

12. On Eratosthenes' calculation see Figure 14. For discussions see the literature cited at Lloyd (1987) 231 n. 55; note especially Taisbak (1973–74), Newton (1980), Rawlins (1982a) and (1982b), and Gratwick (1995). For further literature see González (2000) 214–217.

13. Syene is in fact about 3° east of Alexandria. For *(E1)* and *(E2)* see also Strabo 2.5.7, where *(E1)* is qualified as "approximate."

14. Cf. also II.1.197–209 for this assumption.

15. Eucl. *El.* 1 prop. 29.

ratio) to their own circles, as is also demonstrated by geometers.[16] (For example, when arcs stand on equal angles, then if one of them is one-tenth part of its own circle, all the remaining arcs will also be one-tenth parts of their own circles.)

64: Someone who has mastered these [assumptions] would have no difficulty in learning Eratosthenes' procedure, which is as follows.[17] He says that *(E1)* Syene and Alexandria are located below the same meridian. So since *(def. 2)* the meridians are included among the great circles in the cosmos, the circles of the Earth located below them are necessarily also great circles. Thus the size that this procedure demonstrates for the [arc of the] circle of the Earth through Syene and Alexandria will be in a ratio with the great circle of the Earth.[18]

71: Eratosthenes says, and it is the case, that *(E6)* Syene is located below the summer tropical circle.[19] So when the Sun, as it enters Cancer and produces the summer solstice, is precisely at this meridian, the pointers on the sundials are necessarily shadowless, since the Sun is located vertically above them. (This [shadowless area] is reportedly 300 stades in diameter.)[20] But in Alexandria at the same hour pointers on sundials do cast a shadow, since this city is located further north than Syene. Now

16. Compare Eucl. *El.* 3 def. 11, which concerns segments.

17. As befits a pedagogical treatise, the basic method of calculation is summarized in advance, as at lines 21–26 above.

18. Lines 104–106 below offer the justification for translating the correlatives here (ἡλίκος . . . τηλικοῦτος) as referring to a ratio.

19. For this location see I.4 n. 21. For the absence of shadow at Syene at the summer solstice see Ach. *Isag.* 67.5–6, Plin. *NH* 2.183, Ptol. *Alm.* 2.6, 107.16–20, and Strabo 2.5.7.

20. Only Cleomedes, here and at II.1.211–213 and 270–273, provides this value. Three hundred stades are $\frac{1}{800}$ of 240,000 stades, or $\frac{1}{600}$ of 180,000 stades, the two figures for the Earth's circumference attributed to Posidonius (see n. 10 above). Neugebauer (1975) 655–656, however, suggests that the figure of 300 was derived from the demonstration by water clocks that the Sun is $\frac{1}{750}$ of its own orbit (see II.1.184–191) with 240,000 stades / 750 = 320 stades, rounded off to 300 stades.

since [by *(E1)*] the two cities are located below a meridian (a great circle [by *(def. 2)*]), if we draw an arc from the tip of the pointer's shadow on the sundial at Alexandria round to the base of the pointer, this arc will be a section of the great circle in the sundial's bowl, since the sundial's bowl is located below a great circle.

84: If we next conceive of straight lines produced through the Earth from each of the pointers, they will coincide at the center of the Earth. So since [by *(E6)*] the sundial at Syene is located directly below the Sun, then if we also conceive of a straight line going from the Sun to the tip of that sundial's pointer, the line going from the Sun to the center of the Earth will be a single straight line. If we conceive of a second straight line drawn from the bowl at Alexandria, that is, from the tip of the pointer's shadow up to the Sun, this line and the first one will be parallel [by *(E3)*], since they extend from different parts of the Sun to different parts of the Earth.

94: Now a [third] straight line extending from the center of the Earth to the pointer at Alexandria meets these parallel lines, and as a consequence [of *(E4)*] makes the alternate angles equal. One of these [angles] is at the center of the Earth where the lines drawn from the sundials to the center of the Earth coincide. The other is where the tip of the pointer at Alexandria and the line drawn from the tip of the pointer's shadow up to the Sun through the point where the line touches [the tip] coincide. The arc drawn from the tip of that pointer's shadow round to its base stands on this second angle, while the arc extending from Syene to Alexandria stands on the angle at the center of the Earth.

103: Now the arcs are similar to one another, since [by *(E5)*] they stand on angles that are equal. Thus the ratio that the arc in the bowl [at Alexandria] has to its own circle is the same as the ratio of the [arc] from Syene to Alexandria [to its own circle].[21] The arc in the bowl is certainly determined as one-fiftieth part of its own circle. So the distance from Syene

21. There are in fact three ratios here that are the same: 1:50 :: $\frac{1}{50}$ circle:full circle :: 5000:250,000 stades. Cf. n. 9 above.

to Alexandria is necessarily one-fiftieth part of the great circle of the Earth: namely [by *(E2)*] 5,000 stades. Therefore, the [great] circle [of the Earth] totals 250,000 stades.[22] And that is Eratosthenes' procedure.

111: Also, at winter solstices sundials are positioned in each of these cities, and when each sundial casts shadows, the shadow at Alexandria is necessarily determined as the longer because this city is at a greater distance from the winter tropic. So by taking the amount by which the shadow at Syene is exceeded by that at Alexandria, they also determine this amount as one-fiftieth part of the great circle in the sundial. So it is evident from this [calculation] too that the great circle of the Earth is 250,000 stades.[23] Thus the diameter of the Earth will exceed 80,000 stades, given that it must certainly be $1/3$ of the great circles of the Earth.[24]

121: Those who say that the Earth cannot be spherical because of the hollows occupied by the sea and the mountainous protrusions, express a quite irrational doctrine.[25] For neither is there a mountain determined higher, nor a depth of sea [greater], than 15 stades. But 30 stades has no

22. Only Arrian at Philoponus *In Arist. meteor.* 15.13–15 also gives this figure as 250,000 stades. For 252,000 stades see Galen *Inst. log.* 12.2 (26.21–27.1), Plin. *NH* 2.247, Strabo 2.5.7 and 2.5.34, Theon *Expos.* 124.10–12, and Vitruv. *De arch.* 1.6.9.

23. See Figure 15. Bowen (2002) notes that Cleomedes, in relying on Eratosthenes' figure for the size of the Earth in other arguments (I.5.72; II.1.294–295), may be indicating that he considered it superior. If so, the point of his mentioning this new computation (the work of an unidentified "they") may be that it replicates and confirms the one attributed to Eratosthenes at lines 64–110, thus making the procedure common to both more reliable than Posidonius', which (see n. 11 above) used reported and questionable information for a crucial premise.

24. For the diameter as $1/3$ of the circumference of the circle see I.5.62–63, and II.1.295–301 and 320–323; also Gem. *Isag.* 16.6. The figure of $22/7$ for π, introduced by Archimedes (second century B.C.) is respected by Theon *Expos.* 124.12–17. Cf. also II.1 nn. 69 and 77.

25. On the Earth's sphericity being unaffected by uneven surface conditions see Strabo 2.3.3 (= Posid. F49.131–132 EK), Plin. *NH* 2.160 with 162, Plut. *De fac.* 924A, Sen. *NQ* 4B.11.3, and Theon *Expos.* 124.7–127.19.

ratio to over 80,000 stades,[26] but is just like a speck of dust would be on a ball. The protrusions on the rondures[27] from plane trees also do not stop them from being rondures. Yet these protrusions have a ratio to the total sizes of the rondures greater than that of the hollows of the sea and the mountainous protrusions to the total size of the Earth.

26. That is, there is "no ratio" that affects observations, the sense of this phrase at I.8.1–18.

27. "Rondures" for *sphairia* (literally "little spheres," or here berries) preserves the analogy with a spherical Earth.

CHAPTER EIGHT

1: While the Earth has the size demonstrated through the procedures just described, there are several ways of proving that it has the ratio of a point not only to the total size of the cosmos, but also to the height of the Sun, which the sphere that encloses the fixed stars far exceeds.[1] So even if 100,000,000 pitchers of water may amount to a significant[2] number when conceived of in isolation, they still have no ratio to the sea, not even to the Nile, or any other river of significant size: by the same token, the Earth, with its diameter of over 80,000 stades, appears to have a significant size when assessed in isolation, yet clearly does not have any [significant] ratio to the height of the Sun, still less to the total size of the cosmos.[3] This is because one magnitude must have a ratio to another magnitude when the larger can be measured by the smaller[4]—when, say,

1. This enclosing sphere is the "enclosure" *(periokhē)* or "circumference" of the cosmos; see line 85 below and II.3.49.

2. "Significant" *(axiologos)*, i.e., "expressible in a ratio."

3. Thus in this context the size of the Earth is, as Ptol. *Alm.* 1.6, 20.5–6 says, "relative to perception" *(pros aisthēsin)*; see n. 8 below.

4. This is true, though it is also true that two magnitudes can be in a ratio when the smaller does *not* measure the greater. For the general definition of a

it is 10 times larger or, if you like, even 10,000 times so. But the [single] pitcher of water would not measure the sea, not even the Nile. So just as the pitcher has no [significant] ratio to the [quantities] mentioned, so too the size of the Earth has no [significant] ratio to the size of the cosmos. This is proven by innumerable [arguments] that involve essentially geometrical demonstrations.[5]

19: *(a)*[6] Although the Sun is much larger than the earth and sea combined, it sends out to us (as will be demonstrated in what follows) an appearance of being about 1 foot wide, despite being very bright. We can thus form the notion that the Earth, if we should look toward it from the height of the Sun, would either not be seen at all, or be seen with the size of a minuscule star;[7] but if by hypothesis we were elevated to a distance far beyond the Sun, and right up to the sphere of the fixed stars, the Earth would not be seen by us at all, not even if imagined as having a brightness equal to [that of] the Sun.[8] Hence the [fixed] stars too must be larger than the Earth, in that they are visible from it, whereas the Earth could not be seen from the height of the sphere of the fixed stars. The Earth is certainly far smaller in size than the Sun, since the Sun itself too, if imagined at the height of the fixed stars, will perhaps appear as large as a star.

32: *(b)* That the Earth is a point in relation to the size of the cosmos

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ratio see Eucl. *El.* 5 defs. 3 and 4. On the idea of measurement see Eucl. *El.* 5 defs. 1 and 2 (for magnitudes), and *El.* 7 defs. 3 and 5 (for whole numbers).

5. Cf. I.5.124.

6. Cf. II.3.51–59 on the size of heavenly bodies, and lines 158–160 below.

7. Under such conditions the Earth would appear to be moving in the same orbit as the Sun moves when observed from the Earth.

8. This argument is irrelevant to the main thesis of the chapter, which concerns the smallness of the Earth's radius in relation to the distances of bodies such as the fixed stars, in other words, the absence of parallax in observations made from the Earth of such distant bodies (see Figure 16). It is the relative distance of those bodies, not the Earth's inherent size, that determines the observational situation, namely, that the observations made from the Earth's surface are the same as if taken from the center of the Earth.

is also evident from observing the heavenly bodies: that is, they are not only visibly equal in size from every part of the Earth, but also similar in shape.[9] Neither [observation] would result unless the straight lines falling from every part of the Earth to all parts of the heavens were equal to one another. The Earth must, therefore, have the ratio of a center[10] to the whole cosmos.

37: *(c)*[11] The *dōdekatēmoria* of the zodiac also prove this: that is, precisely six of them are seen above the Earth, and the bulk of the Earth[12] does not conceal a single degree, indeed not even a small fraction of a degree, since precisely 180 degrees are always detected above the Earth. That is, half of the equinoctial circle is always above the Earth, as is evident from the equinoxes, where nighttime exceeds daytime not even by a hair's breadth;[13] and that would not happen if the Earth's bulk cut off any part of the equinoctial circle—that is, if the 80,000 stades of that bulk were in some [significant] ratio to it.

46: *(d)* Something like the following is seen among the phenomena.[14]

9. At I.6.13–15 the Earth's centrality in the cosmos is demonstrated from the observation that heavenly bodies do not appear unequal from different terrestrial locations. Cf. also II.5.112–114 where the equal distances of the signs of the zodiac are noted.

10. "Center," *qua* geometrical center, is frequently used in the same sense as "point" *(sēmeion)* in this chapter.

11. The arguments of *(c)* can also demonstrate the centrality of the Earth (see I.6.33–34), and be used in estimating the size of the Sun (see II.2.7–10).

12. The Earth's "bulk" *(bathos)* is its third dimension (cf. the specification of its diameter at line 45 below), and equivalent to *onkos*, "volume" (see lines 82 and 92 below, and cf. I.1.32 and 61).

13. On the day of the equinox, nighttime and daytime are observed to be equal; in other words, the Sun's day circle is then the equinoctial circle, and is divided in half by the observer's horizon. Cleomedes is assuming that the Sun is at the equinoctial point when it rises above the horizon rather than reaching this point during the course of the daytime or nighttime.

14. This indefinite expression *(toiouton ti)* alone suggests that the observations that follow are not precise; see further n. 16 below.

There are two stars,[15] identical in both color and size, and directly opposite one another. One occupies the 15th degree of Scorpio; the other, which belongs to the Hyades, occupies the 15th degree of Taurus.[16] Their color resembles that of Mars, and they are always observed on the horizon at the same time, with the one rising as the other is setting. This would not occur if the bulk of the Earth could obstruct any part of the zodiacal circle: for although one star rises and the other sets at the same time, the setting of the one that has risen would anticipate the rise of the

15. These are Antares (α Sco) and Aldebaran (α Tau). These stars are exactly opposite in longitude, but not in latitude, although they are also both close to the zodiacal circle. See Ptol. *Alm.* 7.5 and 8.1.

16. Neugebauer (1975) 960 notes that since Cleomedes' values for the longitude of Aldebaran and Antares differ by 2⅓° from those given by Ptolemy (who likewise puts the stars opposite to one another), and then, assuming *(a)* a constant of precession of 1 degree per century, and *(b)* the accuracy of Cleomedes' values, he argues that the *Caelestia* would have to be dated to the fourth or fifth century A.D., some 233 ± 50 years after A.D. 138, the epoch of Ptolemy's star catalogue. But this argument takes for granted that the values of Cleomedes' longitudes are tropical, or determined in relation to a fixed vernal point, in the same way as are Ptolemy's, and ignores the possibility that they are sidereal longitudes determined in relation to the fixed stars in the Babylonian style. Yet it is now clear that "Babylonian" methods were not supplanted in Greco-Latin astronomy by Ptolemaic methods immediately on the publication of the *Almagest* and *Handy Tables*, but continued to flourish for at least several centuries more; see, for example, Jones (1997) and (1999). Moreover, *(b)* is questionable on grounds of language (see n. 14 above), and from the general quality of Cleomedes' astronomical evidence. Cleomedes' error may in fact be much larger than the ½° that Neugebauer envisages, especially if Cleomedes is making the vague claim that the stars are in the middles of their signs more precise than he ought. There is certainly precedent for this sort of misleading precision in the history of astronomy. Hipparchus himself (*In Arat. et Eudox. Phaen.* 2.1.20–22 [132.10–134.2]; cf. ibid. 1.2.18–20 [20.4–22.9]) claimed that Eudoxus put the tropic and equinoctial points at the midpoints of their respective zodiacal signs, though to judge from Hipparchus' own quotations of Eudoxus, Eudoxus made only the much less precise remark that these cardinal points are in the middles of their respective constellations. See further Bowen and Goldstein (1991) 241–245.

one that is setting by the total interval of time in which it was necessary for the one rising over the part of the heavens obstructed by the bulk of the Earth to become visible on the horizon.

57: *(e)* Sundials also offer a major proof that the Earth has the ratio of a center to the heliacal sphere,[17] since the shadow of the Earth revolves along with the Sun, as Homer clearly indicates when he says: *The shining light of the Sun fell in the Ocean, dragging black night over the fertile land.*[18] Since the Earth's shadow is always in opposition to the Sun and is conical in shape, the very tip [of the shadow] is necessarily opposite the center of the Sun.[19] Sundials that have the shadows of their pointers completing a circular course along with the shadow of the Earth are, therefore, marked out on the Earth by experts.[20] So since no sundial can be marked out at the exact center of the Earth, although one can be marked out in every part of it, obviously the whole Earth has the ratio of a point to the height of the Sun, and thus to the sphere conceived of from it.[21] <Also, every tip on a pointer must have the ratio of a center to the heliacal sphere>,[22] since there obviously cannot be several centers belonging to a single sphere. This means that the pointers on all the sundials that can be marked out on the Earth have precisely the ratio [to the heliacal circle] they would have even if they were con-

17. See also Ptol. *Alm.* 1.6, 20.13–19, Theon *Expos.* 128.5–11 (after emendation), and Calcid. *In Tim.* 111.8–17.

18. *Iliad* 8.485–486; cf. also II.6.22–23.

19. See II.6.4–8.

20. They represent the diurnal course followed by the shadow cast by the unilluminated portion of the Earth, and so, in the literal sense of the verb used *(sumperinostein)*, they "come back home [to their original position] by going round with" that larger shadow.

21. The sphere is "conceived" or "imagined" *(nooumenē)* (cf. line 77 below, and II.1.72), since it is like the limit of a body, which in Stoic ontology "subsists in mere thought" *(kat' epinoian psilēn);* cf. *SVF* 2.488.

22. The sentence in angle brackets has been transposed from lines 66–67 above, where it interrupted the argument.

tracted into a single point.[23] So since there is no part of the Earth on which a sundial could not be set up, the whole Earth has the ratio of a point to the Sun's height and to the sphere conceived of from it.

79: No problem need be raised here about how the Earth, with the status of a point in relation to the size of the cosmos, sends nutriment up to the heavens, as well as to the bodies encompassed by them, despite the heavenly bodies being so large in number and size.[24] That is because the Earth, while minuscule in volume, is vast in power in that virtually alone it comprises most of the substance [of the cosmos]. So if we imagined it totally reduced to smoke or air, it would become much larger than the circumference of the cosmos, and not only if it became smoke, or air, or fire would it become much larger than the cosmos, but also if it were reduced to dust. (We can, for example, see that even wooden objects that disintegrate into smoke expand almost without limit, as does vaporized incense, and every other solid body that is reduced to vapor.) And if we imagined the heavens, along with the air and the heavenly bodies, contracted to the compactness of the Earth, they would be compressed into a volume smaller than it. Thus while in volume the Earth may be a point in relation to the cosmos, since it has an indefinable power (that is, has a natural [capacity] to expand almost without limit), it does not lack the power to send nutriment up to the heavens and to the bodies in them. And this [process] would not cause the Earth to be totally expended, since the Earth itself also acquires something in turn from the air and the heav-

23. Goulet (204 n. 206) claims that here Cleomedes has forgotten the principle underlying Eratosthenes' calculation of the size of the Earth in I.7: that shadows vary depending on the latitudes at which sundials are located. But the present argument turns on the observation that in defining the *paths* of shadows in sundials, no account need be taken of the size of the Earth; see Ptol. *Alm.* 1.6, 20.16–19.

24. Terrestrial exhalations are celestial nutrition in Stoic cosmobiology; see, for example, *SVF* 2.650 (196.8–11), 663, and 690, Posid. F10EK, and cf. Cic. *De nat. deor.* 2.83.

ens. For "the way up is the way down" (to quote Heraclitus),[25] given that <the> substance [of the cosmos] is naturally disposed to be completely transformed and changed by yielding in every way to the artificer for the administration and continuing stability of the whole cosmos.[26]

100: So while the Earth has the ratio of a point to the height of the Sun, some use arguments of the following kind to establish that it does not have the ratio of a point to the sphere of the Moon.[27] *(a)* The distances of the [lunar sphere] from the fixed stars are said not to appear equal at every latitude, but larger and smaller at the same hour for different [observers]. Yet this would not be the result if the straight lines drawn from the Earth to the height of the Moon were equal, for then the distances of the [lunar sphere from the fixed stars] would also appear equal. *(b)* The eclipse of the Sun is also adduced as a sign[28] of this [conclusion], in that it is not eclipsed to an equal extent for all [observers], but it is frequently eclipsed totally, partially, or not at all for different [observers].[29] This would not result if the Earth were a point in relation to the height of the Moon rather than being at an [observationally] significant distance.

25. See Heraclitus at DK 22B60.

26. This "craftsman" *(dēmiourgos)* is fire, or an "artificer" *(tekhnikos)* (e.g., *SVF* 2.1032). The active principle in Stoic physical theory also "crafts"; see *SVF* 2.300.

27. See Plut. *De fac.* 921D (cf. Cherniss [1951] 138) on "certain mathematicians" who were said to argue that there is no lunar parallax. The question of lunar parallax (that is, whether observations taken on the Earth's surface can for practical purposes be treated as though they were taken at the Earth's center) is different from the question about whether the Earth is at the center of the lunar sphere. Note that Cleomedes speaks of the Earth as having the ratio of a center to the solar sphere, but does not think that the Earth lies at the center of this sphere (cf. I.4.53–62). Cf. also Ptol. *Alm.* 4.1, esp. 266.1–4. Aristarch. *De magn.* prop. 2 (352.5–6) does not allow for lunar parallax.

28. A sign *(sēmeion)* is an observable indication of something that is not directly observable (cf. *sēmeioutai* at II.1.216). On the elaborate theory of signs in Stoic epistemology see Burnyeat (1982).

29. That is, it is often the case that a *single* solar eclipse is observed as total or partial by different observers, while being invisible to everyone else.

And this is why the Moon conceals [the Sun] either totally, partially, or not at all for different [observers].[30]

113: Some use the following arguments to claim that the Earth does not have the ratio of a point [to the size of the cosmos].[31]

114: *(a)* They say that when elevated our sight observes objects that are not observed at ground level but are concealed beneath the horizon, and it does this to an increasing extent the higher it is elevated; therefore the heavens are not divided equally from every part of the Earth, and this is considered evidence that the Earth does not have the ratio of a point [to the size of the cosmos]. Our response must be that this [kind of observation] is caused by the sphericity of the Earth's shape. Thus even if the Earth were one stade in size, the result would be identical, just as long as the Earth is centrally located [in the cosmos] and has a spherical shape. (And of course it could not be claimed that an Earth of such limited size did not have a ratio of a point to the cosmos!) So in this case the Earth's shape must be held to be the cause.

124: Also, if someone extended in thought a plane from every point on the Earth,[32] there would not be more, or less, of the heavens seen above the Earth, but an equal amount at an elevation as well as at ground level. Of course the size of the heavenly bodies appears equal at an elevation as well as at sea level.

127: But if someone at this stage said that the half of the heavens above the Earth was not observed at ground and sea level, but only at extreme heights, their claim might have some rationale, since [in some cases] the heavens are certainly divided into two equal parts at extreme heights, but not at ground level, where instead less [than half] is visible above the Earth.[33] But, in fact, it is irrelevant to our argument whether *more* [of

30. See II.3.71–75.

31. The arguments that follow were obviously created for dialectical purposes, not as the record of positions actually adopted.

32. Cf. Figure 1 or Figure 5(a).

33. Both the language and logic of this sentence are awkward. The point seems to be that the contrast in the extent of horizons between a plane and an elevated

the heavens] is observed above the Earth when our sight is elevated, since this necessarily results from the Earth's shape being spherical. What must therefore be offered is evidence that the Earth is not a point in relation to the whole cosmos—[that is], not as to whether it is possible to see more than half the heavens when our sight is elevated, but as to whether an equal amount of them is *not* seen above the Earth [when viewed] from plane surfaces,[34] given that the horizons at ground level are planar, while those seen from an elevated position are, and are called, conical.[35]

140: There is the additional claim *(b)* that different parts of the Earth would not be frigid, torrid, and temperate, unless the Earth maintained distances from the sphere of the Sun that were [observationally] significant; that instead, if the Earth were a point [in relation to that sphere], the Sun would not even be described as approaching us and as withdrawing again. Now here, as with *(a)*, the response must be that the Earth's shape causes all these [phenomena] too: that is, some locations are torrid, frigid, or temperate depending on how the Sun's rays are sent down to the latitudes of the Earth.[36] (This is observed even in relatively small subdivisions that are also a short distance from one another. Certainly, some [places] in Elis are parched, while the adjacent [part] of Achaea has no extreme heat at all.) So even if the Earth were of minuscule size, the result would be the same, in that the Sun's rays are not sent

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position may on occasion be such that a horizon of 180° can only be observed from a relatively elevated position. "Ground level" *(ek tōn khthamalōn)* here may therefore be a valley (cf. the example at I.5.92–94) rather than the planar horizons envisaged later in the paragraph. However, the special conditions involved are not clearly identified.

34. For this to occur, the Earth would either have to be displaced from the center of the cosmos (cf. I.6.33–35), or the cosmos be much smaller, or the Earth much larger. This is also a consequence of the theory refuted at II.6.123–145 (see II.6 n. 16), that more than 180° is seen from ground level over the curvatures of the Earth.

35. Strabo 1.1.20 infers the Earth's sphericity from the enlarged horizon seen from an elevated location.

36. See I.2.73–80.

down to all its latitudes in the same way, but in a perpendicular and intense form in the case of some latitudes, while obliquely and in a diminished form in the case of others. Also, the Sun's approach to us and its subsequent withdrawal are identified with respect to its relation to our zenith, since the straight lines produced from the Earth to Cancer and Capricorn are equal to one another.[37]

157: That the Earth has in fact the ratio of a center [to the cosmos] is demonstrated by these and many other [arguments]. But having in our opening argument[38] stated that the Sun sends out to us an appearance of being about 1 foot wide, despite its being much larger than the Earth, it is this very [claim about its size] that we must demonstrate next by offering in sufficient number for the present introduction [arguments] derived from a group of authors, including Posidonius,[39] who have written treatises exclusively on this subject.

37. That is, the Sun at the summer and winter solstices is not at determinably different distances from the Earth, but is in a different relation to the Earth considered as a sphere.

38. Lines 19–21 above.

39. Posidonius reportedly demonstrated that the Sun was larger than the Earth in a book of one of his treatises (F9EK; cf. Romeo [1979] 14–15), but Cleomedes' reference to other authors implies that not the whole of *Caelestia* II.1 is derived from Posidonius. Theiler nonetheless makes this chapter his F290a.

Book Two of Cleomedes' The Heavens

OUTLINE
Book Two

Chapter 1. The Sun is not the size it appears to be, as the Epicureans believe, but has a size calculable as far larger than that.

Chapter 2. The Sun is larger than the Earth.

Chapter 3. The Moon, other planets, and stars are not the size they appear to be.

Chapter 4. The Moon is illuminated neither by inherent light, nor by reflection, but by the mingling of the Sun's light with the Moon's body.

Chapter 5. The phases of the Moon are caused by its motion in relation to the Sun and the Earth.

Chapter 6. Lunar eclipses are caused by the Moon falling into the Earth's shadow.

Chapter 7. *Appendix:* Data on the extremal latitudes of the planets, the maximum elongation of the inner planets, and the planetary periods; Conclusion.

CHAPTER ONE

2: Epicurus and most of his school[1] claimed that the Sun was the size it appeared to be[2] because they followed only the sense presentation caused by sight: that is, they made this presentation a criterion of its size.[3] We can therefore see what follows from their claim: namely, that if the Sun is the size it appears to be, it is quite clear that it will have in total more than one size, in that it appears larger as it rises and sets, but smaller as it culminates, while from the highest mountains it appears extremely large

1. Since the Epicureans are mentioned collectively at lines 414–415 and 418–419 below without any qualification, this phrase (like "most of the Socratic school" at I.5.17) must refer to the whole sect.

2. See Epicur. *Pyth.* 91, Lucr. 5.564–573, Cic. *Acad.* 2.82, Philodem. *De signis* col. 9 (sect. 14 De Lacy [1978]), and Demetr. Lacon (ed. Romeo [1979]) *passim.* The latter two Epicureans both flourished close to the time of Posidonius. On this theory see Sedley (1976) 48–53, Romeo (1979), and Barnes (1989).

3. On the principle underlying this claim, *viz.* that all sense impressions are true, and on the criterion in Epicurean epistemology, see LS sects. 16–17; Cleomedes may have addressed this issue elsewhere (cf. line 408 with n. 95 below). (At I.5.11–13 the belief in a flat Earth is similarly traced to exclusive reliance on visual appearance; cf. I.5 n. 6.) For a defense of the Epicureans against what is obviously Cleomedes' polemical oversimplification of their position see Algra (2000) 181–182.

when it rises.[4] Now either they will have to say that in total it has more than one size, or, if this is obviously absurd, it is absolutely necessary that they concede that it is not the size it appears to be.[5]

13: Some [Epicureans] say that the Sun appears larger to us as it rises (and sets)[6] because its fire is widened by the air through the force of its rapid ascent.[7] But this involves utter ignorance.[8] The Earth, after all, is located at the exact center of the cosmos, and has the ratio of a center to it; it is therefore equidistant from the sphere of the Sun in all directions,[9] and so the Sun does not come near the air either at its rising and setting, or in any other part of its course. In fact the Sun does not even rise everywhere at the same time, but, given the Earth's spherical shape, it rises, sets, and culminates at different times in different places. So since it can be both rising and culminating at different places, it will be in total both larger and smaller: larger for those for whom it is rising, smaller for those

4. At lines 47–48 below the same location is associated with an illusion of the Sun's greater distance. As Ross (2000) 868 notes, Cleomedes is mistaken here, since the Sun's size is reduced when viewed from a height; she suggests that his extromission theory of the visual ray (cf. n. 15 below) may have led him to assume that in such cases there was greater refraction through the atmosphere at the horizon. On the general issue of celestial illusions and their interpretation see Ross and Plug (2002).

5. If an object has conflicting appearances, then it is not seen as it really is; see Burnyeat (1979) on this principle in ancient epistemology and cf. n. 16 below.

6. There is no subsequent reference to the Sun's being flattened by the pressure of setting, but that can perhaps be taken as implied.

7. On the possibility of the Sun's being reconstituted by the confluence of fiery particles see Lucr. 5.660–665, who does not refer to the air having the causal role assigned it here. Cleomedes probably has in mind the theory of a diurnally rekindled Sun that is attacked later; see lines 426–466 and n. 105 below.

8. Epicurus was often charged with "ignorance" *(apaideusia);* in addition to line 452 below, see LS sect. 25E-H and Pease (1955) on Cic. *De nat. deor.* 1.72.

9. This only appears to be the case; in reality the Sun's orbit is eccentric in relation to the Earth. See I.4.49–71 and II.5.103–132.

for whom it is culminating—at the same hour of day![10] Nothing is more absurd than this.

26: These kinds of suggestions, then, are utterly meaningless and futile. The Sun appears larger to us as it rises and sets, and smaller at its culmination, because we see it at the horizon through air that is denser and damper (that is what the air closer to the Earth is like), while we see it culminating through less adulterated air. So in the latter case the ray sent out toward it from the eyes is not refracted, whereas the ray sent out to the horizon whenever the Sun rises or sets is necessarily refracted on encountering air that is denser and damp.[11] And in this way the Sun appears larger to us (as, of course, objects in water also appear to us other than they are because they are not seen along a straight line).[12] Therefore all such states must be held to be conditions affecting our line of sight, not as properties associated with the objects that are being seen. (When the Sun is observed from [within] deep wells, at least where this is possible,[13] it also reportedly appears much larger because it is seen through air within the well that is damper. And in this case the Sun cannot, of course, be said to be enlarged for those looking in its direction

10. See II.1.430–437 and 448–452 for analogous reasoning used against the Epicurean explanation of the Sun's orbit as a daily extinction and rekindling at sunrise and sunset.

11. On such atmospheric conditions affecting the appearance of the Sun and its size see Arist. *Meteor.* 373b12–13, *Schol. in Arat. vet.* 419.6–420.2, Posid. F119.12–20 EK (in which Posidonius questions this explanation), Sen. *NQ* 1.6.5, and Ptol. *Alm.* 1.3, 13.3–9. For a discussion, with a translation, of II.1.27–75 in relation to the history of the analysis of the "solar illusion," i.e., the apparent enlargement of the Sun near the horizon, see Ross (2000). For a general explanation of what is known as the celestial illusion, and includes the lunar and solar illusions, see Plug and Ross (1994).

12. Such a case of refraction is analyzed at II.6.178–187, though with reference to the visibility, not the enlargement, of the submerged object.

13. That is, where these (vertical) wells are located at latitudes on or between the tropics, so that the Sun can be observed at zenith from the base of the wells at some point during the year.

from [within] the well, but diminished in size for those doing so from above, but quite clearly the humid darkness of the air within the well causes it to appear larger for the [former] observers.)

45: The Sun's distance [from the Earth] also appears larger and smaller to us: as it culminates it appears very close, but as it rises and sets it appears farther away, while from the highest mountains it appears at a still greater distance. And when it appears close by, it also appears very small; but the more distant it appears, the larger it also seems. The quality of the air causes all such [appearances]: that is, when seen through damp and denser air, the Sun appears larger to us and more distant, but when seen through clear air it appears smaller in size and closer in distance. (Thus Posidonius claims that if it were possible for us to see through walls and other solid bodies, as Lynceus could in the legend, then the Sun, when seen through these, would appear much larger to us and as removed to a much greater distance.)[14]

57: While the Sun appears larger and smaller to us, as similarly do the distances involving it, the [visual] cone that impinges in reality on it from the rays that flow out <from> the eye[15] is necessarily very large. But since the size and distance of the Sun are both contracted to what appears to be an extremely small quantity, we can conceive of two cones: one that impinges in reality on the Sun, the other that does so in appearance.[16]

14. Lines 51–56 = Posid. F114EK; see Kidd *Comm.* 442–443. Lynceus was a legendary figure with preternatural visual powers.

15. Hahm (1978) 65–69 (who ignores Cleomedes) doubts that the early Stoic theory of vision involved rays in the form of visual pneuma flowing out from the eye, as indicated here and at II.6.181–185 (cf. I.1.72–74) where our "line of sight" is like a conical "bead" of pneuma drawn on an object. Note the verb *epiballein* ("impinge") at lines 59, 62, and 234 below, and also II.4.130. For more on the visual cone see lines 253–258 below, and II.5.110–112 (cf. II.5.49–54).

16. A "real" visual cone represents the conditions under which the Sun is seen without any conflicting appearances. See Burnyeat (1979) 73–75 on the implication that an object that is seen by different observers as having conflicting appearances must in principle be visible to all observers with the same appearance.

These will have a single vertex at the pupil of the eye, but two bases: one in reality, the other in appearance. Therefore the real distance is to the apparent distance as the real size is to the apparent size. But the bases of the [two] cones are equal to the real and apparent diameters respectively.[17] Therefore the real distance is to the apparent distance as the real size is to the apparent size. But the real distance is almost immeasurably[18] larger than the apparent one, since the Earth has the ratio of a point to the height of the Sun, and to the sphere conceived of from it. Therefore it is absolutely necessary that its real size be immeasurably larger than its apparent size. Therefore the Sun is not the size it appears to be.

76: Also, if the Sun is the size it appears to be, then if we imagine it being double its size, each of its parts, when divided into two, will appear to be 1 foot wide.[19] So if we also imagined it so enlarged as to extend over a distance of a 1,000,000 stades, each of its parts that is 1 foot wide would appear the size it is. If so, it follows that the Sun would in fact appear the size that it is, although that is clearly impossible: human sight simply cannot attain such a degree of power that objects extended over 1,000,000 stades appear the size that they are in reality, since even

17. Here the Sun is treated like a flat disk; see Figure 17. But at II.5.51–54, with the help of Eucl. *Opt.* prop. 27, it will be shown that less than half of the Moon's sphere is seen by a terrestrial observer.

18. "Immeasurably larger" *(apeirōi meizōn* or *apeiromegethēs)*, literally "larger by an unlimited [amount]," often qualified by "almost" *(skhedon)* (cf. II.1.85, 135, 241, 266, 360), presumably because attempts can be made to calculate the Sun's real size.

19. "1 foot wide" *(podiaios)*, this width being the approximate diameter (cf. the qualifications at I.8.20 and 159) of the flat disk that the Sun appears to be (see n. 17 above, and cf. lines 267–269 below); it is an informal measurement in contrast to more systematic procedures (see II.3 n. 7). The term itself was probably inherited from Heraclitus by Epicurus (see Sedley [1976] 52–53), and is frequent in descriptions of the Epicurean doctrine by secondary sources. As Algra (2000) 187 notes, these distort a claim that may have been intended as a polemical reaction to astronomers' claims about its distance and size. On Aristotle and the philosophical basis for this illusion see Schofield (1978) 113–114.

the cosmos itself, although of almost unlimited size, appears to us to be very small.[20]

87: Now since what follows from the Sun's being 1 foot wide is impossible, it is impossible for it to be 1 foot wide. For it cannot also be claimed that, when the Sun is extended over such a great distance, some of its parts that are 1 foot wide will appear the size that they are, while others will not.[21] That is because the distances from the Earth to all the parts of the Sun will be equal, since the Earth has the ratio of a center to the heliacal sphere. Thus *all* of its parts that are 1 foot wide, not some specific parts more than others, will have to appear the size that they are. So if all its parts that are 1 foot wide appear the size they are, the Sun itself, when extended that much, will appear in total the size that it is. Since this is obviously impossible, its parts that are 1 foot wide will not even appear to be the size they are—instead, they will not even appear at all! So if the Sun itself is 1 foot wide, it will not even appear. But it does appear. Therefore, it is not 1 foot wide. So it is clear from this, I think, that if the Sun were the size it appears to be, it would not appear. But since it does appear, it is not the size that it appears to be.

102: If the Sun is the size it appears to be, and if the sense presentation derived from sight is itself the criterion for the size that belongs to it, it could be said to follow that this appearance would also be a criterion for the [other qualities] that appear to belong to it.[22] Hence if it is

20. "Cosmos" here must refer to the visible celestial hemisphere, which we imagine to be smaller by assimilating the sizes of heavenly bodies to familiar bodies at shorter distances. For an analysis of this illusion see the passage translated from the Arabic as sect. 7 of Ptolemy's *Planetary Hypotheses* Book I, Part 2 at Goldstein (1967) 9.

21. Here we have an imaginary opponent who must have accepted the argument in the preceding paragraph, and is then trying to wriggle off the hook by claiming that the Sun is large in some places, but 1 foot wide in others.

22. This sentence marks a return (until line 139) to arguments based (like those at lines 5–56 above) on conflicting appearances.

the size that it appears to be, it also has the qualities that it appears to have. But it appears hollow, <spinning>,[23] and flashing,[24] although this configuration does not belong to it; certainly at other times it is seen as smooth, Moon-like, and not spinning.[25] Yet is impossible for all these [qualities] to belong to it. Therefore the Sun's being 1 foot wide, of which they are a consequence, is also a falsehood.

110: Again, if the Sun is as large as it appears, and has the qualities it appears to have, then since it also *appears* stationary, it would *be* unchanged in position.[26] Yet it is not unmoved, and so is not unchanged in position. Hence it is also not the size that it appears to be.

114: The absurdity of their claim could also be proved with the utmost

23. This supplement, proposed by R. Renehan at *Caelestia* ed. Todd II.1.106, balances "not spinning" in the next sentence (see n. 25 below). For such spinning see Arist. *De caelo* 290a12–18; it is an optical effect that can occur at both sunrise and sunset.

24. For hollowness and brightness see Arat. *Phaen.* 828–830, and for apparent hollowness caused by interposed clouds see *Schol. in Arat. vet.* 410.8–13 and 411.6–10. Such a shape could be dark, and so *marmairōn* ("flashing") (line 107) might be emended to *melainomenos* ("blackened"; cf. *Schol. in Arat. vet.* 411.8).

25. *μὴ δινούμενος* ("not spinning") (line 108): i.e., the Sun's appearance at times other than sunrise and sunset. Given the evidence at n. 23 above, there is no basis for emending it, either to *μελαινόμενος* ("blackened") (Theiler) (an epithet more appropriate in the preceding line; see n. 24 above), or *μηδὲν πυρούμενος* ("in no way ignited") (Marcovich [1986] 117). Marcovich finds support for his emendation in *πυρωπός* (line 132 below), but *μηδὲν πυρούμενος* must refer to an igneous constitution, not a fiery appearance, and its true parallels are elsewhere: *πυρώδης* at I.5.129, or *πύρινος* at II.3.93, II.5.4, and II.6.104.

26. For this argument, supplied with its major premise ("everything that appears also is the case"), see the Epicurean Demetr. Lacon col. 20, with Romeo (1979) 16 and n. 41, and Algra (2000) 185–186, who uses this text to defend the Epicureans, who were well able to handle this widely recognized type of illusion; see Lucr. 4.391–396, and also Sen. *Ep.* 88.26 and Alex. Aphr. *De an.* 71.17–18 with Todd (1995) 127 n. 26. For the generic case of distant objects appearing stationary although really moving see Sext. Emp. *PH* 1.118.

cognitive reliability on the basis of the following [argument]. If the Sun is indeed the size that it appears to be, it is, I think, evident that the Moon too is the size it appears to be.[27] And if it is so itself, then so too are its phases: so when it is crescent-shaped, the distance from horn to horn is also as large as it appears to be. This further implies that the distances [from the Earth] to the heavenly bodies near the Moon are also as large as they appear to be, from which it further follows that all the distances of the heavenly bodies without exception are also as large as they appear to be. Hence the whole hemisphere of the heavens above the Earth is also as large as it appears to be.[28] But this is not so. Therefore neither is the Sun the size that it appears to be. (Also, if the Moon along with its phases is the size it appears to be, then the black spots that appear in it are also the size that they appear to be. If so, the [Moon's] "mountains" must also be the size they appear to be.[29] But this is not the case. Thus neither is the Sun the size it appears to be.)

129: Now when the air is "pure" (that is, in a natural state), we cannot look back at the Sun. But when the condition of the air enables us to look at it, it appears differently to us at different times: sometimes white, sometimes palish, occasionally fire-like, and is often to be seen as red ocher in color, or blood-red, or yellow, and occasionally even multicolored, or pale green.[30] Also, we think that the pale cloud-like flecks that

27. See Epicur. *Pyth.* 91 and Lucr. 5.575–584 for this as an Epicurean claim. For more on the size of the Moon see II.3.1–33.

28. For Epicurean recognition that the Sun can appear closer than it really is see Lucr. 4.405–413, and Diog. Oen. Fr. 13 cols. I.13–II.10 Smith (1993). Lucr. 4.397–399 (on distinct mountains appearing to coalesce in the distance) could presumably be applied to the distance between heavenly bodies, even if, for an Epicurean, they will still be the size that they appear to be.

29. Goulet 210 n. 237 argues that these mountains are terrestrial. Yet although the Moon, as he notes, is a rarefied body (I.2.37–39, II.3.88–91 and II.4 *passim*), it could still appear mountainous as a result of its unevenly "turbid" appearance (see II.3.89 and II.5.2).

30. See Arat. *Phaen.* 832–879 on the Sun's varying appearances, recorded there as weather signs; cf. "palish" (*ōkhriōn*, line 132) with *Phaen.* 851.

often appear around the Sun belong to it,[31] although they are at an almost immeasurably vast distance from it. Again, often when setting or rising on a mountain peak, the Sun sends out to us the appearance of its touching the peak, although its distance from every part of the Earth is as vast as is to be expected when the Earth has the ratio of a point in relation to its height.[32]

140: So surely it is utterly stupid—is it not?—to follow this kind of sense presentation[33] instead of making something else a criterion, at least for things of such a great size,[34] bearing in mind that being misled in these cases usually causes significant damage.

144: The utter inconceivability of the [Epicureans'] claim is also very clearly proven on the basis of arguments constructed in the following way. Imagine a horse released to run along a plane in the time interval between the Sun's outer rim's emerging over the horizon and its complete emergence.[35] A fairly obvious guess would be that it would advance at

31. On "flecks" *(knēkides)*, pale spots produced by a light cloud that lacks moisture, see *Aratea* 126.24–25. They probably created a halo; see Goulet 210 n. 238, who notes Sen. *NQ* 1.2.3.

32. For the same illusion see Lucr. 4.404–413. This passage is evidence that the Epicureans could handle the issue of the Sun's vast distance, as is Diog. Oen. F13, II.1–10, adduced by Algra (2000) 185. For the constructive use of the illusion see lines 227–232 below.

33. One based just on sight (or visual observations), that is; see lines 3–4 and 102–105 above.

34. The best definition of such an alternative criterion is given at I.5.2–6. Using its language, the Sun is not "fully displayed," and therefore implications about its size must be drawn from phenomena by more elaborate forms of reasoning, initially involving the comparison of different phenomena (lines 145–224 below), and later the use of calculations (lines 225–356 below).

35. At Philodem. *De signis* cols. 10–11 (sect. 15 De Lacy [1978]) a Stoic, Dionysius of Cyrene, is reported as arguing that the Sun must be very large because it reappears slowly from behind an obstruction; the present argument is a rough attempt to measure the speed of this apparent motion. (On Dionysius and Posidonius, whose lives probably overlapped, see Romeo [1979] 14–16.) Cf. also II.2.13–18 with II.2 n. 6.

least 10 stades, whereas a very swift bird would go many times farther than the horse, and again a missile with a very swift momentum would go much farther than the bird, so that in such a period of time it would cover at least 70 stades.[36] Now on the hypothesis that the heavens travel as fast as the horse, the diameter of the Sun would be determined as 10 stades; if as fast as a very swift bird, then much larger; but if as fast as the missile, it would be at least 70 stades. Given all this, the Sun will not be 1 foot wide, that is, not the size that it appears to be.

155: Now we could form the notion that the heavens move immeasurably many times swifter than the missile from the following procedures.

156: When the Persian King was on his expedition to Greece, he reportedly stationed people at intervals from Sousa as far as Athens, so that what he accomplished in Greece could be indicated orally to the Persians through people stationed at intervals successively receiving oral messages from one another. The oral message that progressed through the stages of this relay reportedly reached Persia from Greece in two intervals of a nighttime and a daytime. Now if such a movement (or "impact") of air,[37] although extremely swift, covered a minuscule portion of the Earth in two intervals of a nighttime and a daytime, one can, I think, form a notion of what kind of speed the heavens have, and that it is immeasurably swifter than this, since in one interval of a nighttime and a daytime the heavens go through a distance immeasurably many times greater than that from Greece to Persia.[38]

36. On missile throws as units of measurement see Lucr. 4.408–409. This missile, however, cannot depend on human propulsion, since 70 stades is seven times as far as a horse gallops in roughly 2 minutes. Note that at lines 150 and 153 we have emended the manuscript reading 200 to 70. The minuscule letter used for 200 (sigma) could have been confused with that for 70 (omicron), and 70 also makes more sense of the numbers at lines 166–168 (see n. 39 below).

37. Stoics (see *SVF* 1.74 and 2.138 and 139) defined speech as an "impact" *(plēgē)* on air.

38. For the Persian relays see Hdt. 8.98 and Xen. *Cyr.* 7.6.17–18. This argument is a "procedure" *(ephodos)*, as we have defined it in the Introduction (cf.

166: Also, if we imagined the missile going through the great circle of the Earth, it would not even go through the 250,000 stades [of the Earth's circumference] in three intervals of a nighttime and a daytime![39] Yet the heavens go through the full extent of the cosmos, despite its being immeasurably larger than the Earth, in one interval of a nighttime and a daytime. Thus no notion of the speed—the rapid movement, that is—of the heavens can even be formed, and nothing like it can be interpreted in terms of a ratio. The Poet displays how great the speed of the heavens' course is through the following [verses]: *The dim distance that a man sees with his eyes when sitting on a promontory, looking upon the wine-blue water, is equivalent to one stride of the gods' loud-neighing horses.*[40] But this is expressed in an exaggerated way, and with striking expansiveness. Not only is [Homer] pleased to use the farthest extent of sight to indi-

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n. 38), since it relies on an axiom that could be made explicit as follows: "If two bodies, *A* and *B*, move in circles around the same center, and *A* moves along its circumference farther than *B* does along its circumference in the same time period, then *A* moves faster than *B*." Not surprisingly, Cleomedes does not spell this out. Similarly, the argument that follows (lines 166–170) is an application of the axiom: "If two bodies, *A* and *B*, move in circles around the same center, and *A* moves the same distance along its circumference as *B* does along its circumference, but in a shorter time period, then *A* moves faster than *B*."

39. Since this must be the missile introduced at lines 149–153 above, it will have to cover 200 stades during sunrise if we retain the manuscript reading at 150 and 153 above. Thus if the Sun's diameter is $^{1}/_{750}$ of its orbit (lines 184–191 below), it will rise in $^{1440}/_{750}$ minutes (= 1.92 mins.), and the missile will cover 150,000 stades in a full day. It will thus orbit an Earth of 240,000 (or 250,000) stades in less than 2 full days. But 200 can be plausibly emended to 70 (see n. 36 above), and in that case the missile will cover 52,500 stades in a full day, and, in conformity with the text at lines 167–168 ("not even in 3 days" being taken to mean "in [significantly] more than 3 days"), take over 4 days (specifically 4 days, 18.3 hours) to orbit the Earth.

40. Homer *Iliad* 5.770–772. Milton *Paradise Lost* 8.38 is closer to Cleomedes in saying that the heavens have "Speed, to describe whose swiftness number fails." Although the Homeric verses identify only the sight line from the promontory to a distant horizon, Cleomedes adds additional upward and downward sight lines because of the comparison with celestial horses and the reference to the sea.

cate the speed involved in the rapid movement of the heavens, but also adds to it an upper distance along with the [depth of] the sea below. Yet even this description falls short of properly indicating the swiftness of the heavens. The speed that the heavens employ in their rapid movement has no limit, and no notion of it can be formed. So surely it is stupid to believe that a part of them that is 1 foot wide could rise in such an interval of time?[41]

184: The naïveté of this claim is also proved by water clocks, since these are a means of showing that, if the Sun is *1 foot* wide, then the greatest circle of the heavens will have to be *750 feet*! For when the Sun's size is measured out by means of water clocks, it is determined as $^1/_{750}$th part of its own circle: that is, if, say, 1 *kuathos*[42] of water flows out in the time it takes the Sun to rise completely above the horizon, then the water expelled in the whole daytime and nighttime is determined as 750 *kuathoi*. Such a procedure was reportedly first conceived of by Egyptians.[43]

192: The [Epicurean] doctrine is also refuted by colonnades that face south, since the shadows of the columns are sent out in parallel lines.[44] That would not happen unless the Sun's rays were sent out to each column in straight (i.e., perpendicular) lines.[45] And the rays would not be sent out perpendicularly in the direction of each column unless the diameter of the Sun were coextensive with the whole colonnade.[46]

41. In, that is, the interval determined in the three "guesstimates" (cf. *stokhazesthai* at line 147) at lines 147–153 above.

42. A *kuathos* was 1/6 of a *kotulē*, which was about 1/4 of a liter, or about 1/2 of a modern pint.

43. On ancient accounts of this method see Goulet 210 n. 243 and Kidd *Comm.* 449–450 (add Sext. Emp. *AM* 5.75 to the critics). Cf. lines 297–299 below where this method is applied to the Moon. The "water clock" *(hudrologeion)* must have been a type of clepsydra (see I.1 n. 18).

44. At the latitude of Greece, that is, the shadows would always point in a northern direction.

45. See I.7.53–56 for this principle.

46. Cf. II.3.23–33 for the argument that the Sun and the Moon must both have diameters at least as large as the terrestrial shadow cast by the Moon in a

197: Streets that throughout the inhabited world are arranged facing the equinoctial rising point also reportedly become shadowless when the Sun rises at the equinoxes, a result that is conditional on the Sun's size being coextensive with the whole inhabited world, specifically with its width. Again, at midday at the equinox all the streets in the inhabited world are illuminated on both sides, so that the Sun's size is coextensive not only with the width, but also with the length, of the whole inhabited world. (The length of the inhabited world extends east-west, whereas its width extends north-south.) Thus when the Sun rises on the day of equinox and renders the streets that face it shadowless, it has its diameter coextensive with the width of the inhabited world, whereas when it culminates and illuminates all the streets on both sides, it has its diameter coextensive with its length. (But the Sun is said not to culminate for everyone at the same time, but only for those who live below the same meridian. So it must be stated that the preceding [argument] is expressed rather loosely.)[47]

211: Also, when the Sun is in Cancer, bodies illuminated at Syene become shadowless at exactly midday over [a circular area] 300 stades in diameter.[48] This clearly reveals that the Sun is not 1 foot wide. If it were 1 foot wide, none of this would happen.

216:[49] That the Sun is not 1 foot wide is also indicated by shadows: for when the Sun displays its rim above the horizon, the shadows sent out are very long, but when it is above the horizon they are contracted

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solar eclipse. Here the colonnade is analogous to the Moon, since it is the object that creates a terrestrial shadow when illuminated by the Sun.

47. The caveat is needed, since the Sun rises and reaches culmination at different times at successive meridians (cf. I.5.37–39). We are asked to extrapolate from the situation at a given location to the whole of the inhabited world.

48. See I.7.75–76, and lines 270–273 below.

49. Cf. I.6.9–32, where the evidence of shadows is used in an elementary argument for the cosmocentrality of the Earth. Here shadows serve to indicate the Sun's distance from the Earth, and *eo ipso* the fact that its real size is greater than its apparent one.

to a much smaller size. This would not happen unless the Sun's rays were much higher than all terrestrial bodies, and that would not happen if the Sun were 1 foot wide. Therefore it has a diameter greater even than the highest mountains, since when it is completely visible above the horizon, it sends out rays higher than the peaks of mountains (that is, from a higher position).

225: The following procedure, which goes forward on the basis of the phenomena alone, demonstrates not only that the Sun is not 1 foot wide, but also that it has a prodigious size.[50] For when the Sun rises or sets in alignment with the peak of a mountain, anyone at a significant distance away from the peak sees its rim, which is observable on each side of the peak. This would not occur unless the diameter of the Sun were larger than the peak causing the obstruction. So if this peak is 1 stade in diameter,[51] the diameter of the Sun will have to be larger than 1 stade.[52] (The preceding is said to be observed among the phenomena not just in the case of a mountain peak, but also in that of the largest islands. For when our line of sight is at a significantly elevated position, and impinges on one of the largest islands from a considerable distance away, the island appears so small that here too the Sun's rim visibly protrudes on each side when it rises or sets in line with them. From this it is clear that the diameter of the Sun is also greater than the length of the largest islands.)

240: With this taken [as true] on the basis of the phenomena alone, the next stage is to demonstrate that it is necessary that the diameter of

50. This procedure could be based on Eucl. *Opt.* prop. 5 (cf. II.4.121–122 with II.4 n. 32): i.e., when two objects are aligned relative to an observer, and the closer one blocks (or, in this case, almost blocks) the more distant one, then the more distant object must be the larger of the two.

51. This is its one-dimensional appearance at such a distance; cf. *mēkos,* "length," in line 238.

52. This assumes that in the next illustration there is no distance between the Sun and the peak, or the Sun and the island; i.e., that the Sun is as close to these intervening objects as it appears. Distance will be incorporated in the next stage of reasoning.

the Sun be almost immeasurably greater than the diameters of the largest islands. This is established via the following procedure. *(1)* If an isosceles triangle has a base, say 1 stade in length, and if the sides are produced by an amount equal to those that enclose the base that is 1 stade long, the base of this [second] triangle will then be twice the base that is of 1 stade in length. Then *(2)* if we once more produce sides equal to the whole of the sides [of the second triangle], its base will be four times the base of the triangle [posited in *(1)*], and thereafter the same proportion will progress without limit.[53] Now assume *(3)* that we see one of the largest islands from a considerable distance when the Sun is rising or setting in line with it, with its rim visibly protruding on each side, and that the island is located between us and the Sun. Now *(4)* if our line of sight encompasses the island, the cone formed from the line of sight will have the diameter of the island as its base. So if its diameter is 1,000 stades, then the base of the cone will also be the same size. Now let us hypothesize *(5)* that the Sun is as distant from the island as the island is from us. So since [by *(3)*] the Sun's rim visibly protrudes on each side of the island, the rays that flow from our eyes to the Sun are [by *(1)*, *(2)*, and *(5)*] double [the length of] those that reach the island. Thus [by *(1)*] the base of this [second] triangle will also be double the diameter of the island.[54] If [by *(4)*] the latter is 1,000 stades, the diameter of the Sun will be 2,000 stades, since it is the base of the larger triangle. So since [by *(5)*] the Sun is as distant from the island as we too are on the opposite side of it, the diameter of the Sun will be 2,000 stades. But the distance [in each case] is not equal; instead, we are a short distance from the island, while the Sun is immeasurably many times farther away from us, and so the diameter of the Sun will [by *(2)*] also be almost immeasurably many times greater than the diameter of the island. How, then, could the Sun's size be 1 foot wide when it extends over such a great distance?

53. See Figure 18.
54. See Figure 19.

269: The following kind of procedure reveals better than any other the estimated value for the size of the Sun.[55] [It assumes] *(1)* Syene is located below Cancer; thus when the Sun is located in this sign and stands precisely at culmination, objects illuminated by it are shadowless in this area up to a diameter of 300 stades.[56] With this as true among the phenomena, Posidonius hypothesized *(2)* that the heliacal circle is 10,000 times greater than the Earth's circumference.[57] Starting out from this [premise], he demonstrated that the diameter of the Sun must be 3,000,000 stades. That is, if [by *(2)*] one circle is 10,000 times greater than the other, then the section of the heliacal circle that the Sun's size occupies must be 10,000 times greater than the section of the Earth that the Sun renders shadowless when located overhead. So since [by *(1)*] this section extends to a diameter of 300 stades, the section of its own circle that the Sun occupies at any time must be 3,000,000 stades.[58] But this is taken [as true] on the basis of the aforementioned hypothesis. And while it is plausible that the heliacal circle be no less than 10,000 times greater than the Earth's circumference (given that the Earth has the ratio of a

55. On this calculation see Kidd *Comm.* 443–447 and Neugebauer (1975) 655–656. On problems involved in reconciling it with other reports of Posidonius' determination of the size and distance of heavenly bodies see Kidd *Comm.* 454–456 and 464–466 on F116 and F120 EK.

56. See I.7.71–76, where this premise forms part of Eratosthenes' calculation of the circumference of the Earth.

57. Contrast this arbitrarily stipulated value (a genuine hypothesis) with the value for a terrestrial distance employed in the calculation of the circumference of the Earth in I.7; see I.7 nn. 4 and 11. It is unlikely (*pace* Heath [1913] 348 and Kidd *Comm.* 447) that Posidonius derived the ratio 10,000:1 for the heliacal circle to the Earth's circumference from Archimedes.

58. This calculation, like earlier ones (cf. I.7 nn. 9 and 21, and see n. 73 below), involves two identical ratios (cf. I.5 n. 22). Here 300:240,000 (the ratio between the diameter of the area at Syene and the Posidonian measurement of the circumference of the Earth given in I.7) (or 1:800) is multiplied by 10,000, the hypothesized figure in *(2)*, and the ratio is converted to 3,000,000: 2,400,000,000.

point to it), it is possible that we do not know that it is in fact greater, or again less, than this.[59]

286: The following procedure[60] is therefore considered to carry a greater degree of cognitive reliability.[61] *(1)* In total eclipses the Moon is said to measure out the Earth's shadow twice.[62] (This is because the time interval in which it enters the Earth's shadow is equal to the time interval in which it is concealed by the shadow, so that there are three equal intervals: the one in which it enters; the one in which it is concealed; and the one in which it exits from the shadow on exposing its outermost rim immediately after the second interval.) So since [by *(1)*] *(2)* the Earth's shadow is measured out twice by the size of the Moon, it seems plausible *(3)* that the Earth is twice the size of the Moon.[63] So since, by Eratosthenes' procedure, *(4)* the great circle of the Earth is 250,000 stades,[64] then *(5)* the Earth's diameter must exceed 80,000 stades. Thus [by *(3)*] *(6)* the diameter of the Moon must be 40,000 stades.[65] So since *(7)* the Moon (just like the Sun) is also $^1/_{750}$th part of its own circle (as is estab-

59. Even without this interjection, which is presumably Cleomedes', the hypothetical nature of *(2)* must have been obvious to Posidonius; see n. 57 above.

60. Kidd *Comm.* 444 suggests that the next calculation (lines 286–338) should not be attributed to Posidonius, but since it has an identical axiomatic basis (see n. 73 below), Posidonius could have been its source, if not its original author; cf. also I.7 n. 9.

61. Literally, it involves "some greater degree of clarity," where the clarity is attached to cognitively reliable reasoning; see Introduction 14–15 and II.6 n. 29.

62. See Aristarch. *De magn.* prop. 5 (352.13 Heath [1913]).

63. On the relative sizes of the Earth and the Moon in Stoic cosmology see II.3 n. 19.

64. See I.7.109–110.

65. This rounding off means that the Earth's circumference might as well be 240,000 stades (Posidonius' value) as the Eratosthenean value given in *(4)*. The claim at *(6)* must assume that the Earth's shadow is cylindrical, not conical (cf. II.2.27; II.6.90–108), in shape. See Figure 20. This in turn assumes that the Sun is the size of the Earth.

lished by water clocks),[66] and since *(8)* 1/6th part of its circle is the distance extending to its height from the Earth,[67] it follows [by *(7)* and *(8)*] that *(9)* this distance is 125 lunar magnitudes.[68] But *(10)* each of the 125 lunar magnitudes also has [by *(6)*] a diameter of 40,000 stades. Therefore, *(11)* there are 5,000,000 stades from the Earth to the height of the Moon (at least by this procedure).[69]

304: In addition, hypothesize that *(12)*, based on a simplified reckoning, the motion of the planets that is based on choice occurs at the same speed.[70] Since *(13)* the Moon goes through its own circle in 27½ days, while the Sun has a period of 1 year,[71] *(14)* the heliacal circle must be 13 times the lunar circle.[72] Thus *(15)* the Sun will also be 13 times the size of the Moon (since [by *(7)*] each of them is 1/750th part of its own circle.) Therefore, in accordance with the preceding assumptions, *(16)* the Sun's diameter is determined as 520,000 stades.[73]

66. See lines 184–191 above.

67. This follows, if the diameter of a circle is 1/3 of the circumference; see *(20)* below, and cf. I.7.119–120 (with I.7 n. 24). If the Earth is not "a point" in relation to the orbit of the Moon (cf. I.8.100–112 and II.3.71–80), then *(8)* is a hypothesis, albeit less radical than *(12)*.

68. That is, 750 / 6 = 125. This also assumes that the lunar circle is concentric with the circumference of the Earth.

69. For this value see Apollonius of Perge at Hippolytus *Refutatio* 4.8.6 (101.31). It can also be reached from *(8)* above (i.e., 750 x 40,000/6); it is, in other words, 1/6 of the lunar circle.

70. This hypothesis (cf. lines 334–338 below) is used to explain anomalous planetary motion at Gem. *Isag.* 1.19. The speed in question is not angular but linear; it is the rate at which a planet runs through the circumference of its circular course.

71. These are their sidereal periods given earlier: I.2.28–29 (Sun), and I.2.41–42 (cf. II.3.97–98) (Moon).

72. The computation here is approximate. Cleomedes is considering only the whole number of times the year is divided by 27½.

73. This calculation is again (cf. n. 58 above) implicitly based on an identity between ratios: specifically, 1:13 :: Moon's diameter:Sun's diameter :: 40,000: 520,000.

312: Since *(17)* the heliacal circle (just like the zodiacal circle) is divided into 12 parts, then *(18)* each of its twelfth-parts will [by *(16)*] comprise 32,500,000 stades,[74] and *(19)* the distance from the Earth to the Sun is [by *(8)*] 2 twelfth-parts. (Aratus[75] also states this with reference to the zodiacal circle as follows: *Six times the length of the ray from an observer's eye-glance would subtend this circle*, *and each sixth*, *measured equal*, *encompasses*[76] *two constellations.* Here he has called 2 *dōdekatēmoria* of the zodiacal circle "constellations" *(astra)*, and in the verses quoted reveals that the distance from the Earth to the Sun is $\frac{1}{6}$ of the whole circle.)[77] In other words, while [by *(8)*] *(20)* the whole diameter is $\frac{1}{3}$ of that circle, then *(21)* the distance from every part of the Earth to the Sun is $\frac{1}{6}$ [of that circle; i.e., 65,000,000 stades] (since that circle has as its center the Earth, which is located at its exact center).[78] So since the heliacal circle is determined by this procedure [cf. *(7)* and *(16)*] as 390,000,000 stades, each of its twelfth-parts, as we said [at *(18)*], is 32,500,000 stades. So if the latter too are divided into 30 degrees, just like the *dōdekatēmoria* of the zodiacal circle, each degree will be $1{,}083{,}333\frac{1}{3}$ stades. There will be 720 half-degrees in the whole circle, but the Sun will [by *(7)*] be $\frac{1}{750}$ of it, and hence less than $\frac{1}{2}$ degree. Thus since $\frac{1}{2}$ degree is $541{,}666\frac{2}{3}$ stades, the Sun itself is with probability determined [by *(16)*] as having a

74. That is, $750 \times 520{,}000 / 12 = 32{,}500{,}000$ (see lines 324–325 below). Here, in *(19)* and at line 326 below, *dōdekatēmoria* can be translated as "twelfth-parts," since it is not being used in its technical sense to designate the zodiacal signs (cf. I.4 n. 17 and lines 319 and 328 below) which are each $\frac{1}{12}$ of the zodiacal circle.

75. *Phaen.* 541–543, translated by D. Kidd (1997) 113, with minor changes.

76. At *Phaen.* 543 the best manuscripts of Aratus have *περιτέμνεται* ("intercepts") for the verb in Cleomedes' text, *περιτέλλεται* ("encompasses"). See D. Kidd (1997) 113.

77. The radius of the zodiacal circle is thus taken as $\frac{1}{6}$ of its circumference; see Hipparch. *In Arat. et Eudox. Phaen.* 1.9.12 (94.16–17) and *Schol. in Arat. vet.* 320.13–15. A scholiast in the latter collection (321.4–6), however, notes that the radius is equal to one side of a regular hexagon inscribed in the circle (cf. Eucl. *El.* 4 prop. 15 porism).

78. This is how it appears; for the reality see I.4.57–71.

diameter of 520,000 stades, in accordance with the assumptions as we have made them.

334: Yet it is certainly held to be implausible *(12)* that the planets move at an equal speed in accordance with the course based on choice. Rather, the course of the more distant planets, composed as they are of a more tenuous fire, is much swifter. For how is it possible for the Moon, whose own body is mixed with air, to have its course based on choice equal in speed to those [planets] that subsist from fire, which is tenuous (i.e., extremely light)?[79]

339: So while different claims have been made regarding the size of the Sun, none of the natural philosophers and astronomers has claimed that it has a diameter less than that given above. (Hipparchus, they say, demonstrated that it was 1,050 times the size of the Earth!)[80] So how could it be 1 foot wide when it is determined as being of immeasurable size by every method of reasoning that adopts an essentially systematic procedure?

345: Now since [by *(7)* and *(21)*] there have to be 125 solar magnitudes between the Sun and the Earth, then if the Sun is 1 foot wide (i.e., the size that it appears to be), the Earth's distance from it will have to be 125 feet![81] (That means that the Sun will be located well below the highest mountains, since some of them have a vertical height exceeding even

79. If the varying density of the planets' aethereal mediums causes them to move at different speeds, then their apparent speeds will also necessarily differ, as they would anyway because of their varying distances from the observer (cf. II.5.102–107), even if their real speeds were equal (cf. Eucl. *Opt.* prop. 54, which proves that "when objects move at an equal speed, those more remote seem *[dokei]* to move more slowly," tr. Burton [1945]).

80. On Hipparchus see Toomer (1974–75) 140.

81. Diog. Oen. Fr. 13 col. II.5–8 Smith (1993) argued that the Sun's distance was greater than it appeared; otherwise, it would ignite the Earth. Cleomedes could respond that it would then also have to be larger than it appeared. Furley (1996) 125 argues that the Epicureans are committed to a cosmos in which heavenly bodies are not disproportionately distant from an Earth to which they are proportionate in size.

10 stades.)[82] Thus, on Epicurus' doctrine, the Sun's height (in relation to which the Earth is a point, despite [by *(4)*] being 250,000 stades [in circumference]), is determined as being 125 feet from the Earth. That is what is implied by the doctrine of "the sacred soul who alone discovered the truth"![83]

353: As for the height of the Moon, what could one even say? For if the Sun is 125 feet distant from us, and far lower than mountains, how far distant from the Earth must the Moon be when [by *(14)*] its circuit is, by the minimum calculation, $\frac{1}{13}$ of the solar circuit?[84]

357: But even if Epicurus could pay no attention to these [calculations], nor uncover them in an inquiry that was beyond a fellow who valued pleasure, he should at least have paid attention to the actual power of the Sun, and to have reflected [on the following]: *(a)* that the Sun illuminates the whole sky, which is almost immeasurably large; *(b)* that it heats the Earth so that some parts of it are uninhabitable because of extreme heat;[85] *(c)* that through its considerable power it provides an Earth that is alive[86] so that it produces crops and sustains animal life; and that it alone causes animals to subsist, and also crops to be nourished, grow, and come to fruition; *(d)* that it alone is what causes not only the daytimes and nighttimes, but also summer, winter, and the other seasons; *(e)* that it alone is the cause of people being black, white, and yellow, and

82. At I.7.123–124 a maximum height of 15 stades is given for mountains.

83. Epicurus was frequently lauded in extravagant terms by members of his school; see further Goulet 215 n. 286 and Pease (1955) on Cic. *De nat. deor.* I.43 and 72, and also lines 461–462, 467 and 487–488 below.

84. Cleomedes could have argued that if the Earth is a point in relation to the Moon (implied by *[8]* above; cf. n. 67 above), and if the Moon is 1 foot wide (its apparent size), then for the Epicureans it should also be at the *same* distance from the Earth as the Sun.

85. Cleomedes accepted that the torrid zone was uninhabitable (see I.1.88–89, 210–211, 266–267; and I.2.73–76), and criticized Posidonius' arguments for its habitability (I.4.90–131).

86. *empnous:* literally "endowed with pneuma," i.e., with the force that is, in effect, the soul of the cosmos.

differing in other visible aspects, depending on how it sends out its rays to the latitudes of the Earth; *(f)* that the power of the Sun, and it alone, renders some places on the Earth well-watered and teeming with rivers, others dry or lacking in water; some barren, others adequate for crop production; some acrid and foul-smelling (like those of the Fish-Eaters),[87] others fragrant and aromatic (like places in Arabia); and different places capable of producing different kinds of crops.

376: The Sun is, in general, the cause of virtually all the variety found among things on the Earth, since the Earth shows considerable contrast at some latitudes. We can, for example, learn of the variety of things reported in Libya, in the territory of Scythia, and in Lake Maiotis,[88] where the crops, animals and, in a word, everything are subject to major transformations, including the temperatures of the air, and its varying states. Then there are the differences observed throughout the whole of Asia and Europe[89] in springs, crops, animals, metals, and hot springs, and in every type of air—very cold, very torrid, temperate, light, dense, moist, dry—as finally in all the other differences and peculiarities observed at each latitude. Of all these the power of the Sun is the cause.

387: The Sun, furthermore, has such a great superfluity of power that the Moon too receives its light from it,[90] and so has this as the exclusive cause of all its power in its different phases, since the Moon not only fashions enormous changes in the air by controlling it and thereby fashioning innumerable purposeful results, but is also the cause of the flowing and ebbing of the Ocean.[91]

393: The Sun's power has also a further observable property: that

87. The "Fish Eaters" *(Ikhthuophagoi)* are often associated with the Arabian Gulf; see Hdt. 3.19 and Strabo 16.4.4.

88. This is the ancient name for the Sea of Azov. See Strabo 2.5.23, and also 2.1.16 on its climate.

89. Asia, Europe, and Libya (see lines 378–379 above) were the continents of the inhabited world known to the ancients; see, for example, Hdt. 4.42 and 198.

90. For the details see II.4.21–32.

91. On lunar power see also II.3.61–67.

while fire cannot be extracted by reflection from ordinary fire, we contrive to extract fire by reflection from the rays of the Sun, despite its being such a vast distance away from the Earth.

396: Also, as it goes through the zodiacal circle (that is, as it effects this type of course), the Sun by itself harmonizes the cosmos, and so, by being the exclusive cause of continuing stability in the comprehensive ordering of the whole cosmos, it provides the whole cosmos with an administration that is fully concordant.[92] And if the Sun changes its position, either by abandoning its own place, or by disappearing completely, not a single thing will then be born or grow—in fact nothing will "subsist" at all, but everything that exists and is visible will be dissolved together and so be destroyed![93]

404: Epicurus, then, should have attended to all this, and reflected on whether a fire that was 1 foot wide could have a power that was so extensive, so great, and so prodigious.[94] But in astronomy, in the area of sense presentations, and in every investigation generally, he was the same as in his treatment of the first principles of the cosmos, the theory of the goal of life, and in ethics generally[95]—a man far blinder than a bat![96] No wonder, since pleasure-loving fellows certainly cannot uncover the truth

92. Despite the "administrative" activity of the Sun, it is the heavens in their totality that play this role; see I.2.1–4. An earlier Stoic, Cleanthes (ca. 331–230 B.C.), had represented the Sun as the "controlling organ" *(hēgemonikon)* of the cosmos (*SVF* 1.499), but Posidonius did not follow him; see Kidd *Comm.* 145.

93. See also Cic. *De nat. deor.* 2.91 for this argument.

94. Lucr. 5.592–613 argues that a Sun of extremely small size can cause major terrestrial effects, but concedes the Stoic point by envisaging (at 610–613) an adjacent band of invisible heat that augments solar power.

95. For Epicurus' treatise on the goal of life see Usener *Epicur.* 119.13–123.17 and Diog. Laert. 10.27, and for that on sense presentations Diog. Laert. 10.28. The areas of philosophy identified here could also correspond to the categories of Cleomedes' own program of teaching.

96. The English idiom is used here. The Greek refers to *spalakes* (blind rats or moles), which were thought to have eyes under their skin; see Arist. *De an.* 425a10–11.

in what exists. That is for *men* who are naturally disposed to virtue and value nothing ahead of it, not for lovers of a "tranquil condition of flesh" and the "confident expectation regarding it."[97]

414: In an earlier generation they drummed the Epicureans and their scriptures out of communities in the belief that doctrines that had reached such a level of blind perversion offered people offense and corruption.[98] Today, by contrast, because people are, I think, undone by effeminate luxury, they esteem the members of the sect and their actual treatises so highly that they seem to have a stronger desire for Epicurus and the members of his school to speak the truth than for the gods and Providence to exist in the cosmos. In fact some would even pray for Providence to be destroyed rather than have Epicurus convicted of false statements.[99] That is the wretched state that they are in—so reduced by pleasure that they revere its advocate above everything in life!

426: In addition to all the absurdities mentioned, the Epicureans also claimed that heavenly bodies were kindled on rising, and extinguished on setting.[100] That is just like someone saying that people exist while they are being seen, but die when they are not seen—or his applying like reasoning to every other visible thing! So Epicurus was such a clever and inspired man that it did not even occur to him that, because the Earth has a spherical shape, each [heavenly body] sets and rises at different times in different [regions], and so by his doctrine would have to be extinguished

97. Both expressions were used in Epicurus' "On the Goal of Life" *(Peri telous);* see Usener *Epicur.* 121.34–122.3

98. For corroboratory evidence see Goulet 214 n. 277.

99. On alleged Epicurean impiety see, for example, *SVF* 2.1115–1116, Posid. F22a–bEK, and Usener *Epicur.* 246.20–248.23.

100. This was in fact just one of a set of multiple explanations for the alternation of daytimes and nighttimes, as Algra (2000) 183 notes; see Epicur. *Pyth.* 92, and Lucr. 5.650–662 and 758–761. Ptol. *Alm.* 1.3, 11.24–12.18 refuted it, as did the earlier Platonist Dercyllides (see I.2 n. 9), according to Theon *Expos.* 199.21–22. Posidonius dismisses the audible quenching of the setting Sun at F119.3–6 EK. On the illogic of multiple explanations see Wasserstein (1978) 490–492.

and kindled simultaneously. At every alteration in horizons, that is, there would have to be, in repeated progressions, incalculably numerous cases of the destruction of bodies—bodies that were both destroyed and rekindled, since this would happen at every alteration in horizon.[101]

438: We can learn about the alterations in horizons from countless other [phenomena], but preeminently from reports of [the lengths of] daytimes and nighttimes at the solstices among different races.[102] Thus the [lengths of] nighttime at the summer solstice are reported [as follows for these places]:

Meroe in Ethiopia	11 hours
Alexandria	10 hours
The Hellespont	9 hours
Rome	under 9 hours
Marseilles	8½ hours
Among the Celts	8 hours
Lake Maiotis	7 hours
Britain	6 hours

It is obvious from these [reports] that the Sun sets and rises at different times in different [regions]. This happens also for people below the same parallel circles (that is, with identical seasons), whether they are located further east and encounter the Sun's onset sooner, or in the west and do so later.[103] So if there are countless alterations in horizons (there being a different one at every latitude of the Earth), heavenly bodies will have to be extinguished and kindled incalculably many times. Anything more

101. If the Epicureans thought that the Earth was flat (cf. I.5 n. 6), then horizons would *not* alter (I.5.30–44), but their theory would still have other problems.

102. On Ptol. *Alm.* 2.6, the major ancient evidence on variations in lengths of daytimes, see Neugebauer (1975) 44. For more elementary accounts see Gem. *Isag.* 6.7–8, Mart. Cap. 8.877 (cf. 6.595), Plin. *NH* 2.186, and Strabo 2.5.38–42.

103. These are the *perioikoi;* see I.1.236–251 and cf. I.5.37–39.

unthinkable in its display of every kind of reckless ignorance could not be even conceived!

452: Certainly not even the illuminations of the Moon, despite being very vivid, restrain the Epicureans from such ridiculous claims.[104] I mean, how could the Moon be illuminated and shine throughout the night, if the Sun is extinguished on setting? Or how is the Moon eclipsed on falling into the shadow of the Earth, if it is not even illuminated at all? Or how does it exit from the shadow and become illuminated again when there is no Sun below the Earth? Or how does the Sun itself, if it is extinguished, reach its point of rising again? Epicurus, in fact, believed in an old wives' tale, like the Iberians' report that the Sun on falling into the Ocean makes a noise when it is extinguished like red-hot iron in water. That is how "the first and only man to discover the truth" arrived at this doctrine! And he did not even understand that every part of the heavens is at an equal distance from the Earth, but believed instead that the Sun sank into the sea and rose again from the eastern sea—kindled by water in the east, but extinguished by it in the west![105]

467: That is what the "sacred wisdom" of Epicurus discovered! But, by Zeus, it occurs to me to compare him to Homer's Thersites. For Thersites was the worst man in the Achaean army, as indeed the Poet himself says and portrays Odysseus as saying. His own words are "He was the ugliest man to come to Troy" and so on, while he depicts Odysseus saying to Thersites: "There is no other mortal man, I vow, worse than you."[106] But despite being like this, he still did not keep his peace, but

104. The option of lunar illumination by the Sun is in fact included in Epicurean multiple explanations; see Epicur. *Pyth.* 95–96 and Lucr. 5.705–714.

105. There is no evidence of the Epicureans causally linking solar kindling and extinction with a circumambient ocean. (Ptol. *Alm.* 1.3, 11.24–26 just refers to the Sun falling "to the Earth.") Cleomedes did not mention this additional absurdity earlier, but (cf. lines 13–19 and n. 7 above) only a less bizarre theory of solar reconstruction ("kindling") through interaction with the air.

106. *Iliad* 2.216 and 248–249. On the general topic of the Stoic reading of Homer see Long (1992).

first wrangled boastfully with the kings as though he too had status, then dared rank himself among even the leaders by mentioning "[the women] whom we Achaeans give you first whenever we take a stronghold . . . [the man] whom I or another Achaean might bring in in chains."[107] In this vein Epicurus too boasts of being important, given that he tries to include himself among the philosophers, and not just that, but also affirms the right to take first prize, and thereby reveals himself as more thirstily ambitious than even Thersites. The latter, after all, boasts only of being a prince and an equal to the kings, but does not also assign himself first prize, whereas Epicurus claims that he alone has found the truth through his vast wisdom and knowledge, and so thinks it right that he should also take first prize.

489: That is why I would believe it to be quite wrong for someone to say to *him:* "Babbling Thersites, clear orator though you are, hold off!"[108] For I would not also call *this* Thersites "clear," as Odysseus does the Homeric one, when on top of everything else his mode of expression is also elaborately corrupt.[109] He speaks of "tranquil conditions of flesh" and "the confident expectations regarding it," and describes a tear as a "glistening of the eyes," and speaks of "sacred ululations" and "titillations of the body" and "debaucheries" and other such dreadful horrors. Some of these expressions might be said to have brothels as their source, others to resemble the language of women celebrating the rites of Demeter at the Thesmophoria, still others to come from the heart of the synagogue and its suppliants—debased Jew talk, far lower than the reptiles!

503: But despite being like this in discourse and doctrines, he still does not blush to rank himself with Pythagoras, Heraclitus, and Socrates,[110] even asserting the right to occupy the first place among them, just like

107. *Iliad* 2.227–228 and 231.

108. *Iliad* 2.246–247.

109. For ancient attacks on Epicurus' style, and especially his use of neologisms, see Usener *Epicur.* 88–90, and Pease (1955) on Cic. *De nat. deor.* 1.86.

110. Posidonius respected Pythagoras (T91 and T95EK); for Heraclitus see I.8.96–97; on Socrates, the early Stoics, and the Epicureans see Long (1988).

temple robbers trying to rank themselves with priests and hierophants by asserting the right to hold first place among them! Or imagine Sardanapalus trying to square off against Hercules in an endurance test, and grabbing Hercules' club and lion skin and telling him "I have more right to these!"[111]

511: Will you not be off, evil degenerate, to your saffron-robed whores, with whom you will dally on couches, whether combing purple wool, or wreathed in crowns, or with your eyes painted, or even entertained by the *aulos*[112] in excessive and unseemly drunkenness, and then coming to the final act like a worm wallowing in utterly vile and excremental slime? So will you not be off, "most brazen and shameless soul," routed from Philosophy, to Leontion, Philainis, and the other whores, and to your "sacred ululations" with Mindyrides, Sardanapalus and all your boon companions?[113] Do you not see that Philosophy summons Hercules and Herculean men, certainly not perverts and their pleasures? Indeed, it is evident, I think, to cultivated people that Epicurus has nothing to do with astronomy, let alone with philosophy.[114]

111. The contrast between this hedonistic Assyrian monarch (seventh cent. B.C.) and Hercules was standard; see, for example, Juvenal 10.361–362. On Hercules' club and skin as symbols of strength see Cornut. *Theol.* 63.12–21 (at *SVF* 1.514).

112. This was a reed instrument and the principal wind instrument of Greek music; see Michaelides (1978) 42–46.

113. Leontion was an associate of Epicurus; see Usener *Epicur.* 411 and Pease (1955) on Cic. *De nat. deor.* 1.93. The other names are conventional symbols of hedonism; see *SVF* 3, pp. 198–200, and Goulet 216 nn. 298 and 299.

114. Astronomy, this sentence implies (see Goulet 39 n. 31 on its construction), is subordinate to philosophy, as claimed by Posidonius F18EK (see Appendix).

CHAPTER TWO

1: We have demonstrated that the Sun is not 1 foot wide, and so certainly not the size that it appears to be. Next we shall try and establish that it is larger than the Earth. This has already been in effect demonstrated, yet something else was being primarily established in the earlier discussion.[1] Here, however, we shall speak directly about this [thesis], starting out from the phenomena alone.[2]

7: In the first lecture course we demonstrated that the Earth, through having the ratio of a point [to the size of the cosmos], conceals none of the [celestial sphere's] 360 degrees, indeed not even a small fraction of a degree, since, as is demonstrated by the equinoxes, precisely 180 degrees always show above the Earth, along with the 6 zodiacal signs, and half of the equinoctial circle.[3] So since the Earth does not conceal even a small fraction of a degree, whereas the Sun occupies a magnitude of almost ½ degrees,[4] the Sun is larger than the Earth.

1. In the calculations of the size of the Sun at II.1.286–312 the relative size of the Earth was mentioned only at II.1.294–296 in connection with Eratosthenes' measurement.
2. For reasoning similarly based "directly" on the phenomena see also I.5.104–113.
3. Cf. I.8.37–43 with I.8 n. 11.
4. See II.1.329–330.

13: Now if we also hypothesize something equal in size to the Earth rising or setting [like the Sun], it will not spend any time at the horizon.[5] That is because just as the Earth, given its position in the exact center [of the cosmos], does not conceal even a small fraction of 1 degree, so too something equal in size to the Earth will not spend any time at the horizon when it rises or sets. Yet the Sun both rises and sets over an extended interval of time. It is therefore larger than the Earth.[6]

19:[7] Also, when one spherical body is illuminated by another, then if they are equal [in size] to one another, the shadow of the illuminated body is sent out in a cylindrical form. But where the illuminated body is the larger, the shadow is funnel-like,[8] with its [outer] ends being continually further widened and its forward progress being without limit. But if the body that causes illumination is larger, it is necessary that the shadow of the body that is illuminated be configured in the shape of a cone. Now since both the Sun and the Earth are spherical bodies, and the former causes illumination while the latter is illuminated, it is necessary that the shadow of the Earth be sent out with a shape that is either funnel-like, cylindrical, or conical. But it is neither cylindrical, nor funnel-like.

5. Taking the ratio of the Earth's diameter to that of the Sun as approximately 80,000:520,000 stades (or 1:6.5) (cf. II.1.295–296 and 311–312), then, adapting the example at II.1.145–148, in which a horse ran 10 stades while the Sun rose, the Earth (or a body of equivalent size), located at the same distance from the Earth as the Sun, would appear to rise for a terrestrial observer in the time taken by such a horse to run just over 1.5 stades.

6. For a more elaborate version of this argument by the Stoic Dionysius of Cyrene (a near contemporary of Posidonius; cf. II.1 n. 26) see Philodem. *De signis* cols. 10–11 (sect. 15 De Lacy [1978]), and Barnes (1990) 2661–2662.

7. See Figure 21 for the shapes proposed in this paragraph.

8. The adjective so translated *(kalathoeidēs)* literally means "basket-like," where the container *(kalathos)* has a base significantly narrower than its opening; i.e., it is shaped somewhat like a modern filter funnel, or, in relation to the present context, like an inverted cone, or what Pliny *NH* 2.51 calls a *turbo rectus* (an upright spinning-top).

Therefore it is conical,[9] and, if that is so, the Earth has as the cause of its illumination something larger than it—the Sun.[10] In the discussion concerning the Moon[11] we shall demonstrate that the Earth's shadow is neither funnel-like, nor cylindrical. That, then, is enough on the size of the Sun.

9. This argument (also at Heraclit. *Allegr.* 46, Plin. *NH* 2.51, and Theon *Expos.* 195.5–197.7) implicitly relies on the Stoic "fifth undemonstrated argument" (see I.5.20–29 and I.6.1–8), in which all but one of a set of disjuncts are eliminated.

10. Posidonius (F9EK) argues that the Sun is larger than the Earth because the Earth's shadow is conical in a lunar eclipse.

11. At II.6.79–108.

CHAPTER THREE

1: The notion that the Moon too is not the size that it appears to be can also be formed from what was said above about the Sun (that is, most of what was said there can also be applied to the Moon),[1] but it is the eclipse of the Sun that primarily demonstrates this. That is because the Sun is eclipsed only when the Moon passes under it, and obstructs our line of sight; a solar eclipse, in other words, is a condition affecting not the Sun, but our line of sight.[2] So whenever the Moon passes under the Sun such that it is in conjunction with the Sun, and at that conjunction is located on the circle through the middle [of the zodiacal band],[3] it necessarily sends out to the Earth a conical shadow, reportedly extending over more than 4,000 stades (the Moon's shadow equals the total area in which the Sun is invisible when the Moon moves below it). So if its conical shape is extended over this much of the Earth, or even more still, the base of the cone (also equal to its diameter)[4] is clearly many times larger.

1. On the apparent size of the Moon see II.1.114–128 (with II.1 n. 27 on the Epicureans).
2. For this definition see *SVF* 2.650 and Posid. F125EK. See also II.4.127–131.
3. That is, it is located on the zodiacal circle.
4. See also II.1.67.

15: Also, an observation of the following kind occurred at a solar eclipse.[5] On an occasion when the Sun was totally eclipsed at the Hellespont, it was observed at Alexandria as eclipsed beyond 1/5 of its own diameter,[6] which is just over 2 digits in appearance. (The apparent size of the Sun, that is, and similarly of the Moon, is held to be 12 digits.)[7] So from this it is clear that the 2-digit appearance of the size of the Moon and Sun is coextensive with a distance on the Earth equivalent to that between Alexandria and the Hellespont, both of which are located below the same meridian.[8] So if by hypothesis the [conditions] of this eclipse remain fixed, then for people initiating a journey from Alexandria to the Hellespont the 2-digit appearance[9] of the Sun seen at Alexandria would become proportionately less. As there are 5,000 stades from Alexandria to Rhodes, and another 5,000 from there to the Hellespont, the appear-

5. The eclipse is that of March 14, 189 B.C.; see Neugebauer (1975) 316 n. 9. It was recorded by Hipparchus; see Pappus *In Ptol.* 5.11 (68.5–9), and cf. Préaux (1973) 255–256.

6. In other words, the Sun was obscured to 4/5 of its diameter.

7. Cf. II.4.117, and see Figure 22. By Ptolemy's time (cf. *Alm.* 6.7), it was the practice to define the maximum obscuration or magnitude of an eclipse in terms of digits, where 1 digit *(daktulos)* is 1/12 of the diameter of the eclipsed body. The eclipse in question thus had a magnitude of 12 digits in the Hellespont and almost 10 digits in Alexandria. Such digits are not the same as those digits of angular measure which are found in Babylonian astronomical texts, and amount to 5' of arc each (cf. Toomer [1984] 322 n. 5). Nor are they the digits, or finger's-breadths, that were 1/16 of a foot *(pous)*, or 1/12 of a hand's span *(spithamē)*.

8. There is in fact no such coextension (or alignment). As Neugebauer ([1975] 964) notes, the "obscuration of one sphere by another does not vary linearly with the displacement of an observer on a third sphere."

9. *phasis:* the term translated "appearance" here is being used, as it often is, as a synonym for the commoner term for appearance, *phantasia;* cf. line 20 above for "the 2-digit appearance *(phantasia)*." In astronomy, however, it acquires the more technical sense of "appearance at a significant configuration with the Sun" (cf. Toomer [1984] 22). Thus the fixed stars and planets are said to have phases, e.g., the first visibility of a fixed star at sunset, and at II.5.70–71 Cleomedes refers to "the phase of [lunar] illumination."

ance of the Sun seen at Rhodes will necessarily be 1 digit.[10] Then as they go from Rhodes to the Hellespont, this appearance too will be proportionately diminished, and will finally be out of sight when they reach the Hellespont. So clearly, if the 2-digit appearance of the size of the Moon and Sun is coextensive with so great a quantity of the Earth, it is necessary that their whole bodies be coextensive with 6 times such a quantity of the Earth.[11]

34: From this procedure the notion can be formed that the [remaining] heavenly bodies too are of enormous size (but certainly not the size they appear!), and particularly the fixed stars, which are the farthest away.[12] For while the difference in their sizes is observed to be large, none appears less than 1 digit. Venus in fact sends out the appearance of 2 digits, making its diameter 1/6 of the Sun's diameter, assuming that they are the same distance from the Earth, but otherwise in proportion [to their true distances].[13] The size of the bodies that appear 1 digit in diameter is 1/12 of the Sun's diameter, if they are assumed to be at the same height as the Sun, but since they are at a greater height, the proportion of their [true] distance will be taken into account.[14]

10. Strabo 2.5.40 gives the approximate distance from Alexandria to Rhodes as 3,600 stades, and that from Rhodes to Alexandria in the Troad as 3,400.

11. Here again (cf. I.7 nn. 9 and 21, and II.1 nn. 58 and 73) a calculation is implicitly based the principle that two ratios (or spatial coextensions) are the same: i.e., 2 digits:10,000 stades :: 12 digits:60,000 stades. The implicit conclusion, then, is that the Sun must have a diameter of at least 60,000 stades, sufficient to show, as a preliminary "notion" (cf. *ennoein* at line 34 below, and I.1 n. 40), that the Sun is not the size it appears to be.

12. For the Epicurean claim that the fixed stars are as large as they appear see Epicur. *Pyth.* 91, and Lucr. 5.585–591.

13. All supralunary heavenly bodies are "fiery" in proportion to their distance into the fire-sphere of the aether (II.1.335–336; cf. II.5.4), yet inherent luminance is not a factor in this analysis, or in that offered in the next paragraph.

14. Here this formula is used to admit that a celestial distance *is* incorrect, just because it is a pure hypothesis. Cf. I.7.46–47 (with I.7 n. 11) where it is a safeguard against the plausible measurement of a terrestrial distance being incorrect.

43: Thus the question of whether some heavenly bodies are also equal to the Sun's size, or even exceed it in size, should not be abandoned. If, for example, one of them were elevated so far that the Sun, if also imagined elevated just as far, will be seen possessing the size of a star, then it will be equal [in size] to the Sun. But if elevated farther, it will be larger in proportion to its height. So since the fixed stars at the outermost circumference of the heavens are very distant, though none is less than 1 digit in appearance, they will all be larger than the Sun.[15] (Furthermore,[16] the Earth, being a point in relation to the height of the Sun, would either not be seen at all by a human being when seen from the height of the Sun, or else would be seen to have the size of an extremely small star, whereas from the sphere of the fixed stars it would not even be seen at all, <not even if assumed to be equally as bright as the Sun>.[17]) It is evident, then, that all the stars seen at this height from the Earth are larger than the Earth, as of course is the Sun itself too, to which many fixed stars are also probably equal in size, or even exceed it in size. That, then, is our discussion concerning this topic.

61: As for the size of the Moon (specifically its not being 1 foot wide) evidence can also be derived from its power, since it not only illuminates the whole sky, fashions major changes in the air, and has many things on the Earth in sympathy with it, but is also the exclusive cause of the ebbing and flowing of the Ocean.[18]

65: The preceding [discussion] is an adequate argument that neither the Sun, the Moon, nor any other heavenly body, is the size it appears to be.

15. This visibility is caused by a luminance that increases in proportion to the distance from the Earth; see n. 13 above.

16. This parenthesis (lines 51–55) repeats I.8.21–26, where the radius of the Earth is shown to be negligible in most celestial observations.

17. The clause in angle brackets is at lines 52–53 in the manuscripts, where it disrupts the reasoning; here it parallels the argument at I.8.25–26.

18. On the Moon's "power" see II.1.387–392. On the causation of tides see Posid. F138EK, and cf. F106EK.

68: Now while none of the other heavenly bodies (at least those visible to us) is held to be smaller than the Earth, astronomers claim that the Moon is smaller than the Earth,[19] offering as their primary evidence the fact that its diameter measures out the Earth's shadow twice.[20] Again, at solar eclipses, as we have already said,[21] the Sun has been observed partially eclipsed at Alexandria during a total eclipse at the Hellespont. This would not happen unless the Earth had a significant size relative to the Moon:[22] in other words, if there is this much difference over a distance of 10,000 stades, the Moon evidently does not cast a shadow on much of the Earth. But if the Moon were equal to, or larger than, the Earth, it would cast a shadow on a considerable area of it during its courses below the Sun. But in fact there will even be areas of the Earth where the Sun is totally visible, while it is being totally eclipsed elsewhere.

81: The Moon does appear large, in fact equal in size to the Earth, and larger than the other heavenly bodies, when in reality it is smaller than they, since it is closest to the Earth of all the heavenly bodies, and thought to be located right at the junction of the air and the aether.[23] That it *is* the closest of all [the heavenly bodies] to the Earth is demonstrated from [the following considerations].[24] *(a)* For those who view the

19. The Stoics (*SVF* 2.666) and Posidonius (F122EK) are both reported as claiming that the Moon was larger than the Earth. Theiler (2.179) and Kidd (*Comm.* 472) are reluctant to attribute this view to Posidonius, and argue that he agreed with Aristarchus that the diameter of the Moon is half that of the Earth (cf. II.1.286–288). See also Pease (1955) on Cic. *De nat. deor.* 2.103.

20. See II.1.286–288 on this being determined at total lunar eclipses.

21. At lines 15–33 above.

22. I.e., if it was not observationally insignificant (or "a point") in relation to the Moon; see I.8.106–112 and cf. I.8 n. 2.

23. See also I.2.37–38.

24. Statements *(a)*–*(e)* all record observations. The physical theory introduced in *(b)* is not essential to the argument from observation. Thus the Moon's proximity to the Earth, like the cause of its eclipses (see II.6.35–36; cf. II.6.56 and 194–196), is directly demonstrable from the phenomena.

Moon with special care it is demonstrated by sight alone,[25] since no other heavenly body goes under it, whereas it is seen to pass under all the planets. From this it is demonstrated that they are more distant than it. *(b)* Its own body is mixed with air, and is rather murky [in appearance],[26] because it is not in the unadulterated [part] of the aether, like the rest of the planets, but, as we have said, at the junction of the two elements [the air and the aether]. *(c)* The Moon alone falls into the Earth's shadow, but none of the other heavenly bodies do; otherwise they would at different times appear brighter and fainter, since every body that is composed of fire appears brighter in a shadow, but fainter under the rays of the Sun.[27] *(d)* In contrast with the other heavenly bodies the Moon has a unique sympathy with bodies on the Earth, just because of its greater proximity to the Earth.[28] *(e)* It goes through its own circuit in 27½ days,[29] whereas no other planet has a period of less than 1 year.

100: It is evident from these [phenomena] that the Moon is the closest to the Earth of all the heavenly bodies.

25. "Sight alone" would not, of course, be an adequate criterion for establishing the nature of something unobservable; cf. I.5.1–9.

26. See II.5.1–4, and II.5 n. 3.

27. See II.6.101–105, and cf. Sext. Emp. *PH* 1.119. Also cf. II.4 n.10 below on the special case of the Moon.

28. See lines 61–67 above.

29. See I.2.41–42.

CHAPTER FOUR

1: There have been several theories concerning the illumination of the Moon.[1] Berossus actually claimed that the Moon was "half fire," and that it moved with a plurality of motions.[2] First is the one in longitude;[3] second the one in latitude (that is, in height and depth [relative to the zodiacal circle]), which is also seen occurring in the case of the five planets;

1. For the three theories considered in this chapter see Apuleius *De deo Socratis* 117–119, with Donini and Gianotti (1982). For the association of the third theory (lines 21–78) with Posidonius see nn. 8 and 19 below.

2. Jacoby *FGrH* 3.C.1, no. 680, at 395–397 distinguished this Berossus from Berossus the Babylonian, a historian of the third century B.C. (Lines 1–9 here = Jacoby Fr. 18; lines 1–17 = Schnabel [1923] Fr. 18.) But his view is still being debated; see, for example, Burstein (1978) 31–32 and Verbrugghe and Wickersham (1999) 13–15 for arguments against the distinction, and Kuhrt (1987) 36–44 for an able defense. On Berossus' lunar theory see Vitruv. *De arch.* 9.2.1 and Lucr. 5.720–730. For a reconstruction see Toulmin (1967).

3. Here we have emended Todd's text at II.4.3 by deleting a clause that states that this motion in longitude is one "which occurs together with this cosmos." The problem with such a qualification is that it would identify Berossus' first motion as the Moon's diurnal motion, which is not longitudinal, whereas its longitudinal motion is sidereal, i.e., in the opposite direction to the cosmos (as identified collectively for the planets at the I.2.8–11). In this way we address the problem of the omission of sidereal motion raised by Goulet 220 n. 336. We

and third is the one around its own center. Berossus believes that the Moon waxes and wanes as it rotates with this third motion, that is, as it turns different parts of itself toward us at different times, and that this rotation occurs in a time equal to its reaching conjunction with the Sun.

10: His doctrine is easily refuted. First, since the Moon exists in the aether, it cannot be "half fire" rather than being completely the same in its substance like the rest of the heavenly bodies.[4] Second, what happens in an eclipse also conspicuously disconfirms this theory. Berossus, that is, cannot demonstrate how, when the Moon falls into the Earth's shadow, its light, all of which is facing in our direction at that time, disappears from sight.[5] If the Moon were constituted as he claims,[6] it would have to become *more* luminous on falling into the Earth's shadow[7] rather than disappear from sight!

18: Others say that while the Moon is illuminated by the Sun, it illuminates the air by reflection, as is seen happening also with mirrors, bright silver objects, and the like.

21: A third option claims that the Moon's light is mixed both from its own <body>[8] and from the Sun's light, and that such a [state] comes about

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regard the text at II.4.2–3 as having been contaminated by the reference to the motion that "occurs together with the cosmos," which was probably originally a gloss that was mistakenly inserted into the text. For planetary latitudinal motion at lines 4–5 see I.2.64–69.

4. The Moon, that is, cannot have two radically distinct parts, if it is located in the aether, since while the aether may be less dense at greater distances from the Earth (cf. II.1.336), it must be equally dense at any specific distance. On the other hand, it may be difficult to differentiate the Moon if it shares in all the physical properties of its medium; see Todd (2001).

5. See lines 82–94 below for an account of how lunar eclipses occur by the theory advocated in this chapter.

6. That is, if it were inherently luminous by being "half fire."

7. For this principle see II.3.91–95 and II.6.103–105; also Plut. *De fac.* 933D.

8. This supplement, confirmed by lines 80–81 below, rules out the interpretation of this third theory as involving the admixture of two kinds of light: solar light and an inherent lunar light. Goulet 221 n. 346 rightly rejects this proposal, made by Cherniss (1957) 123 n. c, who is followed by Kidd *Comm.* 474–475. If

through its not remaining unaffected. That is, unlike solid bodies that give off light, it does not have solar rays rebounding from it and illuminating the air by reflection in a process of reception that involves its reciprocating the rays and thereby sending them back in our direction. Instead, the Moon is altered by the light of the Sun, and through such a blending possesses its own light not intrinsically, but derivatively[9] (just as fully heated iron possesses light derivatively), since it is not unaffected, but is transformed by the Sun. This option is sounder than the one claiming that the Moon causes illumination by reflection because rays rebound from it, as is seen happening where bodies that are solid give off light.

33: The impossibility of the Moon sending out light by reflection might be best summarized by the following [arguments].

34: *(a)* It is not impossible for reflection to occur from relatively solid bodies (reflections are also seen occurring from water, since even water is to some extent compact), but it *is* impossible for reflection to occur from rarefied bodies. After all, how could reflection occur from air or fire,[10] when such bodies are naturally disposed to absorb light rays, yet are not illuminated by them just on the surface, but fully absorb

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nothing else, inherent lunar light is excluded by the criticism of Berossus' theory above. Also, *pace* Kidd *Comm.* 476, this theory of admixed lunar light could be Posidonian (cf. n. 19 below). The fact that at Posid. F127EK the Moon is called "luminous and fiery," and at F122.1–2 EK is said to be mixed from air and fire, does not mean that it also has an inherent and visible lunar light. Any such luminance can be totally lost (see lines 82–94), while any inherent light is visible only under special circumstances (see n. 10 below).

9. *kata metokhēn:* literally, "by participation."

10. Air and fire mingle at the point of their conjunction (I.2.37–38; II.3.83–84) in the lower part of the aether, where the Moon is located (see line 11). The Moon is therefore "mixed with air" (II.3.88; II.5.2 and 6), but too low in the aetherial fire-sphere to be inherently luminous. Hence its igneous component furnishes a "murky" appearance, clearly visible only when the Moon is darkened during a lunar eclipse; see I.2.38, II.3.89, and II.5.2–4 with II.5 n. 3.

anything that impinges on them, just as sponges invariably absorb water?[11]

42: *(b)* The light from bodies that illuminate by reflection is sent out a short distance, but the Moon not only sends out its luminance as far as the Earth, but also illuminates the whole sky. Yet bodies that illuminate by reflection do not send out luminance even 2 stades, as can be seen with mirrors as well as with every single body that illuminates by reflection.

48: *(c)* If anyone suggests that in illuminating by reflection the Moon sends its light farther than the [solid] bodies just mentioned because it is extremely large, we shall respond that both small and very large bodies that illuminate by reflection are subject to the same proportional progression:[12] that is, a larger area will be illuminated by large bodies in respect of length, yet light will certainly not be sent out a greater distance forward. Instead, whether the body that illuminates by reflection is 1 foot or 1 stade wide, it will send out its light over a distance that is equal in respect of its depth.

56: *(d)* It is in addition quite evident that if the Moon caused illumination by reflection, it would not illuminate the Earth at either the crescent or the quarter.[13] That is because objects that illuminate by reflection send out their light at right angles, and so, since the Moon is spherical, its light would be sent out to the west in the phases just men-

11. On lunar density see the problems and solutions at lines 81–94 and 95–107 below. Since the Moon's "sponginess" does not allow it to be totally permeated by its absorbed light (lines 101–102 below), *di' holōn* (line 40 here) must be translated "fully" rather than "totally." See also n. 24 below.

12. That is, the larger the reflecting surface, the larger the volume of air illuminated two-dimensionally ("in respect of length").

13. For this argument see also Plut. *De fac.* 929F-930A. The ancient Greeks used *dikhotomos* (literally "cut in half") to describe the Moon when the Sun's light illuminates exactly half of its face. This happens at what we call the first and last quarters.

tioned, and thus straight toward the Sun.[14] Indeed, not even when full would it cause illumination with the whole of its circle. It would do so if its shape were flat,[15] but since it is a sphere and thus has the extremities of the circle that is visible to us sloping round,[16] illumination from these sloping [extremities] will be sent out at equal and right angles, with the result that only the very middle of the Moon will illuminate the Earth, not its whole circle. In other words, the light from the very middle of the Moon can be sent toward the Earth at right angles, but the light from its sloping [extremities], which do not face the Earth, cannot. So if the Moon caused illumination by reflection, its whole circle would not illuminate the Earth. But it is evident that the Earth *is* illuminated from its whole circle.[17] In fact, as soon as its outer rim rises above the horizon, it illuminates the Earth, although its parts that slope round face the heavens, certainly not the Earth. So since the Moon illuminates not only with its middle, which faces the Earth, but also with its sloping [extremities], which do not face the Earth, clearly it does not send out its light by reflection.[18] Instead, it is because it is illuminated through-

14. The argument here is compressed. Cleomedes posits that spherical mirrors send out their light at right angles to their surfaces, i.e., radially (cf. Goulet 222 n. 350). His point is that the Moon, when it is at the crescent or quarter, would thus not reflect any light to the Earth. See Figure 23. Stephen Menn has raised in a private communication the intriguing possibility that Cleomedes has garbled a somewhat better argument, originally framed in terms of reflection at *equal* angles, by casting it as one about reflection at right angles.

15. Cf. II.5.37–40 where a Moon with a flat shape is also said to be incapable of undergoing phases.

16. The adjective *periklinēs* ("sloping round"), used frequently in this context, refers to the bulbous nature of a hemispherical body. It is used, for example, of the dome of a building.

17. Cf. Plut. *De fac.* 930E on lunar illumination geometrically demonstrated as occurring by reflection from a curved surface.

18. This conclusion is reached without taking into account the size of the Moon, and its distance from the source of its illumination. When noted at lines 102–103 below, they are used to defend the view that the Moon cannot be totally penetrated by the Sun's light.

out by the rays of the Sun (that is, has its light in a blended form) that it illuminates the air.

79:[19] Since the Moon causes illumination in this way rather than by reflection, obviously its light is blended both from its own body and from the rays of the Sun. Yet there are thought to be the following problems [with this theory].

82: *How does the Moon's light disappear as soon as it falls into the shadow of the Earth?* Conversely: *How is the same [light] visible in it as soon as it leaves [that shadow]?* But there is no need to raise this problem and puzzle over it when something similar is seen when the *air* is illuminated.[20] If, for example, a light is brought into a darkened room, the internal air is immediately illuminated; and if the light that illuminates it is extinguished, the air is darkened at exactly the same time as the extinction.[21] This is also seen occurring in the case of the Sun when at its rising the air is immediately illuminated, while it is darkened at the same time as the Sun is concealed by the horizon.[22] (Even if by hypothesis the Sun is extinguished by falling into the Ocean,[23] not only would the air be dark-

19. The three problems that follow (lines 79–126) are sufficiently interconnected to have had a common source, which was probably Posidonius, even though he is only mentioned (line 98) in connection with the second. (Theiler F291 stops, without good reason, at line 107.) Kidd's hesitation on this point (*Comm.* 475–476) is based on his interpretation of the earlier theory of lunar illumination as the blend of lunar and solar light. But, as we have seen (n. 8 above), that theory is one of admixed light, to which Posidonius could have subscribed; in that case, he could have defended it by all three of the arguments presented here.

20. Since the Moon is a separate body, and not just any random volume of air, the analogy here is loose.

21. Alex. Aphr. *De an libr. mant.* 139.17–19 argues that light cannot be suddenly extinguished in a confined space, if it is, as his Stoic opponents claim, a body.

22. But the "northern lights" (I.4.196–207), and refractively caused solar illumination (II.6.168–177 and 187–191), can both occur after sunset.

23. This is the Epicurean theory, criticized at II.1.459–466.

ened when this happened, but it would also get dark at exactly the same time as the extinction.) It is not, I think, at all puzzling to have a similar result in the case of the Moon, too, whenever it falls into the shadow of the Earth. Such is the nature of bodies that are rarefied.

95: Another problem raised in this area is: *Why in solar eclipses do the rays of the Sun not send out light by completely penetrating the Moon, as they do clouds, which are denser than the Moon?* Posidonius duly responds that not only is the surface of the Moon illuminated by the Sun (as in the case of solid bodies that have only their surface illuminated), but that the Moon, as a rarefied body, has rays from the Sun penetrating it to a very great distance, yet not totally.[24] The reason is that the Moon has a considerable volume because of its very large diameter, and because the Sun is no small distance from it. Cloudy air,[25] by contrast, inasmuch as it has no volume,[26] takes in rays that easily penetrate it. (It may be relevant to mention that the Moon's compactness, through which the rays of the Sun cannot escape, also has a unique physical quality.)[27]

108: A further problem raised is: *How does the Moon, as the smaller [of the two], conceal*[28] *the Sun by obstructing its whole body, that is, by being coextensive with its whole diameter?* Now some predecessors believed that in

24. Since the Moon is like a sponge, though not one fully permeated by water (see n. 11 above), lunar illumination does not directly exemplify the "total blending" involved in Stoic cosmology, where pneuma pervades the cosmos totally; cf. I.1.72–73, and see Todd (1976) 29–73.

25. That is, rarefied air. For clouds dense and voluminous enough to reflect sunlight see II.6.171–173, with II.6 n. 22.

26. "Volume" here, and in the preceding sentence, translates *bathos*. Cherniss (1957) 103 n. c argues that, as at Plut. *De fac.* 929D, this term refers to density. But the reference to the Sun's distance implies that when its rays reach the Moon they are weak enough for the latter's volume to block them. Density is introduced as an afterthought; see next note.

27. Kidd *Comm.* 457 and 478 is probably right to see this parenthesis as Cleomedes' own comment. It certainly conveys some reservations about volume alone being able to explain the Moon's absorption of solar rays.

28. "Conceal" translates the verb *episkotein*, although it literally means "cast darkness on," a sense applicable to lunar eclipses (see line 133 below).

total [solar] eclipses when the centers of the deities are in a straight line, the rim of the Sun is observed encircling the Moon by protruding in all directions.[29] But this is not part of what we detect; if it were, then, since the Sun is much larger than the Moon, the protrusions would be seen by us as extremely bright rather than as revealing a minimal extension. So it must be said that although the Moon is smaller than the Sun, nothing prevents its concealing the whole of the Sun, since it is equal, at least in appearance, to the Sun.[30] That it is equal in appearance is also evident just from a [solar] eclipse, but is best proven from the following procedure:[31] when a body is positioned at an appropriate distance, and conceals the whole diameter of the Moon by being coextended with its total size, it also conceals the Sun. And, in general, there is nothing to prevent larger bodies being concealed by smaller ones, and this can be caused in several ways. After all, even in our ordinary experience extremely small bodies conceal mountains and whole seas, and at all events whatever conceals something does not have to be either larger than what is concealed, or even equal to it.[32]

29. Cleomedes is effectively reporting the view that all total solar eclipses are annular; cf. P. Par. 1 col. 19.16–17, a papyrus document dating from the second century B.C.

30. This equality can be calculated by water clocks (II.1.184–191 and 297–299), or expressed through "digital" measurement (II.3.15–43). Cleomedes would appear to be siding with Ptolemy here in the view that there are no annular eclipses of the Sun, i.e., that all total eclipses of the Sun entail complete obscuration. According to Ptol. *Alm.* 5.14, 417.1–11, while the apparent diameter of the Sun is constant, the apparent diameter of the Moon is the same as that of the Sun only when the Moon is at apogee, i.e., at its farthest, and hence smallest; see Neugebauer (1975) 106.

31. It is a "procedure" *(ephodos)* because an axiomatic principle derived from optical theory (see n. 32 below) is applied to observations.

32. The principle involved here (cf. also II.1 n. 50) can be seen as a corollary and extension of Eucl. *Opt.* prop. 5 (8.6–7) ("objects of equal size unequally distant appear unequal," tr. Burton [1945] 338). Thus two objects of unequal size (the Moon and Sun) are unequally distant, yet appear equal when they are aligned

127: The Sun, then, is eclipsed through being obstructed by the Moon; certainly this happens only at their conjunction.[33] Also, a solar eclipse is a condition affecting not the deity itself, but our line of sight: that is, when the Moon comes between us and the Sun, our line of sight, since it is obstructed by the Moon, cannot impinge on the Sun. A lunar eclipse, by contrast, is a condition affecting the deity itself, since the Moon, whenever it falls into the Earth's shadow, is deprived of the Sun's light and plunged into darkness. This happens whenever the Sun, the Earth, and the Moon are in a straight line. That the Moon is eclipsed only by falling into the shadow of the Earth will be demonstrated once we conduct our discussion concerning the wanings and waxings of the Moon.[34]

at "an appropriate distance" (*summetron diastēma*, line 119) so that the nearer and smaller object obscures the more distant and larger one.

33. Knowledge of solar, as well as lunar, eclipses was assumed earlier at I.5.39–44, I.8.106–112, II.1.455–457, II.3.4–33, and lines 12–17 above.

34. That is, in II.6.

CHAPTER FIVE

1:[1] The Moon, as has been demonstrated,[2] exists in closest proximity to the Earth of all the heavenly bodies. It therefore has its body mixed with air and somewhat murky, and this becomes particularly striking in its total eclipses.[3] Now just as the Sun also naturally illuminates every other body that is not totally composed of fire, so too it casts its rays on, and illuminates, the Moon, which is both compact and mixed with air. Accordingly, the part of the Moon that is turned to the Sun is illuminated.

8: Now if the Moon always maintained the same relation to the Sun, then a single part of it would always be illuminated. But since, in accordance with its motion based on choice, it approaches the Sun at one time and withdraws from it at another, as it goes from conjunction to full Moon and from full Moon to conjunction, the light from the Sun therefore goes

1. Cf. the account of lunar phases given up to line 40 below with Gem. *Isag.* 9.
2. At II.3.81–99.
3. Since the Moon has no inherent light (see II.4 n. 8), the murkiness evident in total eclipses can only result from its inherent, but relatively limited, heat. That is, it is located at the edge of a fire-sphere, the aether (II.4.11), but acquires part of its substance from the adjacent element air (I.2.37–38; II.3.83–84; lines 2 and 6 here). Its heat is then notably visible in the darkness of an eclipse, since bodies composed of fire are always more luminous under such conditions (II.3.93–94).

round the whole Moon in its circuit of it.[4] By moving relative to its illumination from the Sun, the Moon is, in other words, affected in just the same way as is the Earth through being stationary. The Earth, that is, always has an equal amount of light from the Sun, yet, in the course of the Sun's period, has different parts illuminated by it at different times. This is because both the Sun's luminance and the Earth's shadow complete a circular course along with[5] the Sun, and the tip of the Earth's shadow is directly opposite the center of the Sun. In this way the Moon too always has the same [amount of] light from the Sun (it is certainly not illuminated in differing [amounts] at different times!), yet different parts of it get illuminated at different times, as it approaches the Sun and again withdraws from it, and in this way it has the light from the Sun encircling the whole of its body.

24: Thus at conjunction it is the hemisphere of the Moon facing the heavens that is illuminated, since that is the part of it facing the Sun at that time. But as it passes beyond the Sun, and in proportion to its withdrawal turns its hemisphere that is facing the Earth toward the Sun, it first causes a crescent shape on being illuminated from the side, then a half shape[6] as it increasingly revolves toward the Sun, then a gibbous shape, and after that a full shape when it is in opposition to the Sun. So in the course of reaching opposition from conjunction, the Sun's light goes down from the hemisphere of the Moon facing the heavens to the one facing us, and in this way the Moon is said "to wax" up until full Moon. But when, after being in opposition, it passes beyond opposition, it, by contrast, wanes as the light is carried round from the hemisphere of the Moon facing us to the one that is facing the heavens, right up until conjunction. So if the Moon's shape were flat, it would be full as soon as it

4. In effect, then, the Moon makes one revolution on its axis in a synodic month; cf. II.4.5–9.

5. *sumperinostein;* see I.8 n. 20.

6. *dikhotomos:* i.e., the shape of the Moon at the first quarter (cf. II.4 n. 13). See also lines 73, 88 and 90 below.

passed by the Sun after conjunction, and would remain full until [the next] conjunction. But since it in fact has its shape in the form of a sphere, it produces the types of its shapes in the way described.

41: The cause of the Moon's having differences in its shapes could be more effectively summarized if we used the following procedure to learn what happens to it.[7] Two circles are conceived of in the Moon: *A*, the one by which its dark part is separated from its illuminated part; *B*, the one by which the part visible to us is separated from the part that is invisible. Each of these circles is smaller than *C*, the circle that can divide the Moon into two equal parts, that is, its great circle. Because the Sun is larger than the Moon, it illuminates more than half of it, and thus *A* (the circle that separates the dark from the illuminated part) is smaller than *C* (the great circle of the Moon). *B* (the circle in our line of sight) is, by the same token, necessarily smaller than *C* (its great circle), since we see less than half of the Moon. The reason is that when a spherical body is seen by two eyes, and the distance between them is less than the diameter of the [sphere] that is being seen, the part [of the sphere] that is seen is less than half.[8] So since *B* divides the Moon not into equal, but into unequal, parts, it too is smaller than *C*, the great circle.

56: Both *A* and *B*, however, appear as great circles relative to our perception, and while they always have the same size, they still do not maintain the same fixed position, but cause numerous interchanges and configurations relative to one another as at different times they coincide with one another, or slope to intersection at an oblique angle.[9] Most such intersections are minimal interchanges, but, as is the case with a genus, all are of two kinds: a right-angled [intersection], and one in which they

7. Lines 44–64 involve a "procedure" (*ephodos;* see Introduction n. 38), since their reasoning relies on independently identifiable geometrical and optical principles.

8. This is a verbatim statement of Eucl. *Opt.* prop. 27 (44.14–15); cf. also Plut. *De fac.* 931C.

9. See Figure 24 for the cycle of the phases of the Moon and their correlation with the two circles described in lines 56–80.

intersect obliquely with one another.[10] There are also only two coincidences: when they coincide at conjunction, and at full Moon.

65: Now when the Moon passes by the Sun after conjunction, circles *A* and *B* distance themselves from one another, and slope to intersection at an oblique angle, so that all that is left illuminated, at least in relation to us, is the small [area] between the circumferences of both. This type of transition, from the coincidence of the circles to their intersection, completes the Moon's crescent shape, since as the circles continually move toward intersecting one another at right angles, they also increase the phase of illumination, since the [area] between the intersection of the circles is always illuminated in such a progression.

72: When the figure of intersection reaches right angles, the Moon is seen at the [first] quarter. But when the circles proceed from this figure to obtuse angles, they cause the deity's gibbous shape, while they cause full Moon by again being fully coincident at opposition. Then by proceeding again from this coincidence to yet another, and by completing the same shapes as they wane, they proceed to the point at which all the luminance disappears when the circles *A* and *B* exactly coincide with the part of the Moon that faces the heavens. That is essentially our discussion concerning the waxings and wanings of the Moon.[11]

81: The earliest natural philosophers and astronomers also realized that the Moon acquires its light from the Sun, as is clear just from the etymology of the word—the name of the Moon *(selēnē)* is derived from its always-having-new-light *(selasaeineon)*[12]—as also from the passing on

10. The text of this final part of the sentence is uncertain, and the translation follows a Byzantine paraphrase (see *Caelestia* ed. Todd at II.5.61–62.) which maintains the required meaning.

11. This account of the phases of the Moon completed here ignores the effect of the Moon's motion in latitude, as well as the subtleties introduced at lines 41–56 above.

12. For this etymology see Pl. *Crat.* 409b12. On Posidonius' interest in etymology, which continued an earlier Stoic tradition, see Kidd *Comm.* 77 and 699.

of torches to people entering the festival of Artemis (symbolic of the Moon acquiring its light externally).[13]

87: Earlier [thinkers] claimed that the Moon had three shapes: the crescent, the quarter, and the full (hence the custom of making Artemis also three-faced).[14] More recent ones added to this trio the shape now called "gibbous," larger than the quarter, but smaller than the full, Moon.

92: *Mēn* is applied in four significations.[15] *(a)* The [lunar] goddess is called *Mēn* when she is crescent-shaped,[16] as is *(b)* the actual condition of the air between conjunctions (as we regularly say: "the month *(mēn)* has been humid or temperate"). Also called *mēn* are *(c)* the interval of time between conjunctions, and, finally, *(d)* the interval of 30 days (as in our saying that we have been out of town, or in town, "for a month," without meaning in any way "from conjunction to conjunction," but just the sum total of 30 days). The first two [entities][17] (the crescent-shaped goddess, and the condition of the air) are bodies, whereas the next two are incorporeal, since time itself is also incorporeal.[18]

13. On Artemis and the Moon see *SVF* 2.748, and the further references at Goulet 223 n. 369.

14. For these three shapes linked with Hecate see Cornut. *Theol.* 72.7–13 and cf. Plut. *De fac.* 937F. For the four configurations see Posid. F122EK with Kidd *Comm.* 473.

15. For *(a)* and *(c)* see *SVF* 2.677, p. 199.30–34. For *(c)*, the only astronomically significant sense (as lines 102–141 here show) see Gem. *Isag.* 8.1. For supplementary semantics see lines 148–149 below.

16. *Mēn* was originally a male Anatolian deity (Mannes), represented with a crescent Moon behind his shoulders. Similarity to -μην, the root of the word for "month" (μείς), seems to have led to the form *mēn* being applied to a temporal period.

17. In Stoic metaphysics they are termed "somethings" *(tina);* see, for example, *SVF* 2.331.

18. A "signification" *(sēmainomenon)* for the Stoics is by definition the incorporeal meaning (the *lekton;* cf. I.1 n. 48), in contrast with a corporeal speech-act or the object spoken about; see *SVF* 2.166. It is being used in an extended fashion here to identify the reference of the word *mēn* in *(a)* and *(b)*, as well as the

102: The conjunctions of the Moon with the Sun do not always maintain an equal time interval for the following reason.[19] The Sun, as already stated,[20] gets both closer to the Earth and higher in accordance with its course based on choice. So when it is lower, it necessarily goes through the zodiacal sign more quickly, but when higher does so more slowly.[21] For when it is lower it goes through a shorter arc, but through a longer one when higher.

107: We might learn this too from what happens with respect to the sections of cones:[22] that those near the bases are wider, those closer to the vertex narrower. Now the cones flowing out from the eye to the heavens have the [point] right at the pupils as their vertex, and have the object of vision on which they impinge as their base, and since the Earth is the center [of the cosmos], the bases of the cones flowing out from it to all the zodiacal signs will be equal.

114: Now if it so happened that the Sun moved at neither a greater nor a lesser height, but always kept the same height from the Earth, then it would go through the zodiacal signs in equal periods of time,

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meanings in *(c)* and *(d)*. Although the time intervals identified in *(c)* and *(d)* are called bodies in one Chrysippean quotation (*SVF* 2.665), the incorporeality of time can transfer to the time intervals as intervals, without reference to the bodies that determine their character; see Brunschwig (1988) 106. The point made in this text also applies to the instances of time intervals at II.1.150–151 and 182–183, and II.2.17–18. It shows the extent to which astronomy is being approached from the perspective of Stoic philosophy.

19. The analysis that follows is a commentary on sense *(c)* from the preceding paragraph; it also elaborates the brief reference to the lunar month at I.2.42.

20. At I.4.57–71. See Figure 7.

21. The varying speeds attributed to the Sun here, and then later to the Moon and the other planets, are all apparent (see Theon *Expos.* 135.6–11). The issue of their real motion, which is a function of their density (cf. II.1.334–338 and II.1 n. 79), is ignored in this context.

22. The three propositions introduced in this paragraph are the assumptions for an *ephodos* at lines 114–141.

and in that way its conjunctions with the Moon would also maintain an equal interval of time.[23] But since this is not the case, but the Sun is instead observed moving at its greatest height in Gemini, and at its lowest in Sagittarius, then in Gemini it will go more slowly through the section of the visual cone[24] (a wider one because it is closer to the base), whereas it will go through the section in Sagittarius more quickly, since here, by contrast, the section of the cone is narrower (that is, closer to the vertex).[25]

123:[26] So when conjunction occurs at the start of Gemini, the month will necessarily be abbreviated, since the Moon is moving closer to the Earth there, while the Sun is at its greatest height. That is because the Moon will overtake the Sun while the Sun is still in Gemini, a sign through which it goes in 32 days. But if conjunction occurs near the start of Sagittarius, the Moon will not catch up to the Sun while the Sun is still in this sign, since the Sun takes 28 days to go through it.[27] This month will, therefore, be the longest of all, since the Moon passes through Sagittarius more slowly, and the Sun does so quickly, and so the Moon catches up with it slowly. The result will be proportionate in the intervening signs.[28]

133: In the same way it is also proven that all the planets have high

23. This would be true only if the Moon's circuit was also concentric about the Earth.

24. Literally "the cone that forms the line of sight" *(kōnos tēs opseōs).* That is, every line of sight has visual pneuma in such a shape; see II.1.57–65 and 252–255, and cf. II.6 n. 27.

25. Cf. I.4.62–71.

26. On the duration of lunar eclipses see II.6.68–78, which presupposes the present analysis, as would any account of the duration of solar eclipses. Cherniss (1957) 126 *a* is, however, wrong to claim that the present text applies to solar eclipses.

27. Geminus in his calendar has the Sun taking 32 days to traverse Gemini (108.1 Aujac [1975]), but 29 (rather than 28) to traverse Sagittarius (103.3).

28. Cleomedes seems to suggest here that the Moon's circle has a fixed perigee and apogee (see Figure 25), but this would not be correct.

points and low points [relative to the Earth][29] in each of the zodiacal signs. For given that all the zodiacal signs are divided into 30 degrees, then when planets go through some of them more quickly, and others more slowly, they obviously go more quickly through the sections of the [visual] cones that they encounter when lower, whereas when the sections of the [visual] cones are wider, their passage is slower because of their height. Since all the planets are heightened and lowered, all of their circuits are comparably eccentric, since because of the variation in their heights they are not equidistant from the Earth in every direction.

141: So since the Moon's [circuit] is also like this, it is spread below the zodiacal band at an oblique angle to the whole of it. Specifically, it touches the northern [circle of the zodiacal band][30] to the extent that the Moon itself invariably approaches the northern [regions], and [touches] the southern [circle] in the same way.[31] So, given this, it necessarily intersects with the circle through the middle [of the zodiacal constellations] at two points,[32] which are variously termed "points of contact" *(sunaphai)* or "nodes" *(sundesmoi)*.

29. The terms that describe these distances, *hupsos* and *tapeinōma* (literally "highness" and "lowness"), are also used analogously in astrology to identify degrees of planetary influence; see I.2 n. 22. At I.2.64–69 they refer only to positioning in the zodiac.

30. Like Goulet 223 n. 373, we reject the suggestion in Neugebauer (1975) 962 that the circles approached by the Moon are the arctic and antarctic circles. On the inclination of the Moon's orbit to the ecliptic cf. II.7.1–2.

31. Cleomedes does not commit himself here to identifying the northernmost circles of the zodiacal band with the northernmost and southernmost parallel circles reached by the Moon.

32. We have followed most critics in deleting a relative clause at lines 145–146 that glosses the phrase describing this circle as "that which is called 'heliacal' and 'ecliptic' *(ekleiptikos)*." This clause is awkwardly positioned in the sentence relative to its antecedent, and so is probably a marginal comment added to the text later, given also that the term *ekleiptikos* (sc. *kuklos*) ("ecliptic circle") is attested in only two sources for the period to which Cleomedes' treatise is datable: P. Oxy. 4138a ii.121 (second century A.D. in Jones [1999]) and Ach. *Isag.* 53.9–10 (mid-second to mid-third century A.D.; see Mansfeld and Runia [1997] 300).

148: Just as "the Sun" is used in two senses—both in the sense of itself and that of its light—so we also standardly use "the Moon" in the same two senses.[33]

150: We shall next conduct our discussion concerning the eclipse of the Moon, our object being to avoid sharing with old hags the belief that at eclipses witches drag the Moon down![34]

33. This sentence may have been displaced from a more logical location after line 86 above.

34. On this folk belief see Mugler (1959), Hill (1973), and Bicknell (1984). Cf. II.1.459–461 for a similar ridicule of folk astronomy.

CHAPTER SIX

1: The Moon is eclipsed by falling[1] into the shadow of the Earth whenever the three bodies—Sun, Earth, and Moon—are in a single straight line, with the Earth in the middle. This can happen only at full Moon.[2] And the Moon falls into the Earth's shadow in the following way. The Sun moves, as already stated,[3] with its own circuit located below the circle that is exactly at the middle of the zodiacal band. Accordingly, the Earth, when illuminated by the Sun, necessarily sends out a shadow, as do all other solid bodies that are illuminated. Now since this shadow has a conical shape, it does not occupy the whole zodiacal band, and so is not aligned with its total breadth, since it terminates in a vertex. But this shadow, since it is necessarily directly opposite the center of the Sun right at the exact center of its vertex, is itself also located below the exact middle of the zodiacal band. Now this shadow far exceeds the distance of the

1. "Falling" here and elsewhere translates a compound verb *(peri-piptein)*, the prefix of which refers to the Moon's circular orbit "around" *(peri)* the Earth.

2. For this as a Stoic definition see *SVF* 2.678 (also Posid. F126EK). For other elementary accounts of lunar eclipses see Gem. *Isag.* 11, and Theon *Expos.* 193.23–198.8.

3. At I.2.53–59 and I.4.52–53.

Moon, though without going up as far as the remaining heavenly bodies. So when the Moon is detected as being in opposition to the Sun, and either to the right (that is, north) of the zodiacal circle, or on the opposite side, it evades the shadow of the Earth, and for this reason the Moon is not eclipsed at every full Moon. But when in opposition to the Sun the Moon is detected as being so situated that a single straight line can be extended through the centers of the Sun, Earth, and Moon, then, by falling right into the shadow of the Earth, it is fully eclipsed. The shadow of the Earth, in other words, moves in direct opposition to the Sun, and is, as it were, "dragged" by it, just as Homer says: *The shining light of the Sun fell in the Ocean, dragging black night over the fertile land.*[4]

24: Since the shadow moves along with the Sun in this way, and at its very tip is directly opposite the Sun's center, then the Moon, as it proceeds in accordance with its motion based on choice, meets the shadow moving from east to west as it itself moves west to east.[5] And by falling into the [Earth's shadow] in this way, [the Moon] is deprived of rays from the Sun (just as we too are when someone stands in our way when we are in sunlight). But it is not always the case that the Moon as a whole is darkened by the Earth (that is, totally concealed by its shadow), but on occasion [the Moon is darkened] just partially. This hap-

4. *Iliad* 8.485–486.

5. Cf. lines 38–42 below, and Plut. *De fac.* 932F-933A. The Earth's shadow and the Sun both have a proper motion eastward, that is, in the direction opposite to the daily rotation, while the Moon similarly has a proper motion eastward, although a much faster one. This means that the Moon overtakes the Earth's shadow each month from the west, with an eclipse occurring if it enters this shadow. Cleomedes misleads the reader when he states (in lines 26–27) that the Moon, while moving east, meets the Earth's shadow as this shadow is moving only westward (cf. lines 41–42). For, while it is true that both the Moon and the Earth's shadow, because of the difference in their proper motions eastward, share to different degrees in the diurnal motion from east to west, it is wrong to say that the Moon and the Earth's shadow meet because they are moving in opposite directions.

pens when through being in opposition to the Sun it touches the [circle] through the middle [of the zodiacal constellations], yet is not detected as having its center at the exact middle [of the zodiacal band]; for this is how a specific part, but not the whole, of it falls into the [Earth's] shadow.

35: That the Moon is eclipsed by falling into the Earth's shadow, and only in that way, can be seen from the phenomena alone.[6] *(a)* It is eclipsed only at full Moon (the only time in fact that it can fall into the Earth's shadow while in opposition to the Sun). *(b)* In any total eclipse the parts of the Moon facing the east are seen to be the first to disappear, because as it sets out for the east in a motion opposite to the heavens, it meets the Earth's shadow, which always moves from east to west. But when it starts to emerge after the eclipse, it has those of its [parts] that face the east emerging first. That is, it is absolutely necessary that as the Moon meets the shadow, the first of its parts to encounter the Earth's shadow and be concealed are again the first to emerge after being concealed. *(c)*[7] Whenever the Moon is partially eclipsed, and is affected in this way as it goes down from north to south, then the parts of it that face south necessarily disappear, since in the downward course they take the lead in falling into the shadow and are in this way concealed, whereas the parts that face north escape the shadow. But when the Moon goes up from the south to the north and effects a partial eclipse by being in opposition to the Sun with its center not yet at the exact middle of the zodiacal band (that is, in line with the center of the Sun), then the parts of it facing north are eclipsed, since they take the lead in falling into the Earth's shadow, whereas the parts facing south are visible.

56: So all these [observations] establish for us by essentially visual means that the sole cause for the Moon's eclipse is the process by which on falling into the shadow of the Earth (that is, being darkened by it) it

6. Since "the phenomena alone" *(auta ta phainomena)* here represent "clear" visual evidence (cf. lines 56 and 195), they can serve as a criterion (cf. I.5.4, and II.3 nn. 24 and 25).

7. For lunar motion in relation to the zodiacal circle see II.5.141–147.

is deprived of the impact derived from the rays of the Sun that illuminate the part of the Moon that is always turned toward the Sun.

60: Furthermore, the segments of the Moon that are illuminated at an eclipse are seen to be curved.[8] This too happens of necessity since the Moon, which is spherical, falls into the conical shape of the Earth's shadow, and so its illuminated segments are also seen to be curved. In other words: When a spherical shape encounters a conical shape and has the part that is in contact with the conical shape always disappearing from sight, necessarily the remaining part, which has not yet disappeared from sight, has its shape curved along the segment (that is, is crescent-shaped).[9]

68: The following too has been observed in the case of the lunar eclipse: the Moon effects a total eclipse at a very great height, when very close to the Earth, and at an intermediary distance.[10] When eclipsed at a very great height it emerges more rapidly, but does so slowly when very low, and when in between it also has an intermediary duration for its eclipse in between the [extremes] mentioned. This [variation] clearly reveals that the Moon is eclipsed in no other way than by falling into the shadow of the Earth. That is, when it is eclipsed at a very great height, it emerges more rapidly through encountering the narrower part of the shadow; but when very close to the Earth, it has to go through a wider extent of the shadow, and thus the duration of its eclipse is greater. But when on occupying an intermediary height there is a proportionate outcome, it also has an intermediary duration for its eclipse.

79: This [evidence of varying eclipses] proves that the Earth's shadow also has a conical shape; in fact, these [phenomena], given the way they

8. Because of the general principle introduced at lines 64–67 (cf. also Arist. *De caelo* 297b25–30 and Plut. *De fac.* 932E-F), this proof is an *ephodos* (see Introduction n. 38). On a traditionally related claim, that the curved shadows appearing on the Moon during lunar eclipses demonstrate the Earth's sphericity, see Neugebauer (1975) 1093–1094, who describes it as "mathematically inconclusive."

9. This curve is in three dimensions, not two.

10. At II.5.102–132 the Moon's eccentric orbit was analyzed with reference to the case of conjunction.

are, are proven by one another. That is, a lunar eclipse is demonstrated to occur only by the Moon's falling into the shadow of the Earth; conversely, variations in eclipses of the Moon demonstrate that the Earth's shadow is conical, since the Moon spends a longer time in eclipses that are closer to the Earth, yet emerges more rapidly in eclipses that are at a greater distance from the Earth, whereas in eclipses at intermediary distances the duration of the eclipse is also intermediary. Partial eclipses too show that the Earth's shadow is conical, since the Moon then has segments illuminated in such a way that its shape becomes crescent. This would not occur unless it fell into a shadow with a conical shape.

90: But it is from the following [argument] that the conical shape of the Earth's shadow might be most effectively demonstrated.[11] If its shadow were in fact cylindrical or funnel-like (that is, if the body that illuminates it—the Sun—were equal to, or smaller than, the Earth), then the shadow that was funnel-like would occupy most of the heavens by terminating in a broad span, with the result that not only would the Moon be eclipsed every month, but it would also remain in the [Earth's] shadow all through the night. But if the shadow were cylindrical, it would occupy the whole breadth of the zodiacal band, since it would not terminate in a vertex, and the Moon would be duly eclipsed each month by falling into the shadow. But because the Earth's shadow is actually conical, and so terminates in a narrow vertex, the Moon evades it when it is detected occupying the northern or southern parts of the zodiacal band at full Moon. (If the shadow were cylindrical or funnel-like, it would also advance as far as the [fixed] stars. As a result the stars would at different times have a brighter or fainter appearance: brighter when in shadow, since every body that is composed of fire is brighter in the darkness of a shadow, but fainter when in the rays of the Sun.[12]) As none of this is observed among the phenomena, it is clear

11. At II.2.19–30 this argument was used to demonstrate that the Sun was larger than the Earth. See Figure 21. On the translation "funnel-like" see II.2 n. 8.

12. Cf. II.3.91–95.

that the Earth's shadow is necessarily conical.[13] If so, it is evident that the body that illuminates it—the Sun—is larger than it.[14]

109: Lunar eclipses are such as we have demonstrated. But statements made about paradoxical eclipses seem to contradict the theory that establishes that the Moon is eclipsed by falling into the shadow of the Earth. For some say that a lunar eclipse occurs even when both luminaries are observed above the horizon,[15] and that this indicates that the Moon is not eclipsed by falling into the Earth's shadow, but in some other way. For if an eclipse does occur when both the Sun and the Moon are seen above the horizon, the Moon cannot at that time be eclipsed by falling into the Earth's shadow. Furthermore, if both [Sun and Moon] are visible above the horizon, and if the Earth's shadow can no longer be at the place where the Moon is seen to be eclipsed, then the place where the Moon is located is illuminated by the Sun! If this [theory] is correct, we shall have to lay claim to a different cause for the Moon's eclipse.

122: Earlier scientists confronted with such statements tried to solve this problem as follows. They said that the Moon could fall into the Earth's shadow (that is, be precisely opposite the Sun), even though both the luminaries were above the horizon. This could not happen if the Earth's shape were flat (i.e., a plane), but, because its shape is spherical, both divinities' bodies could be observed above the horizon directly opposite one another. To explain. Because of the protrusions of the Earth's curvatures the [two divinities] will not actually face one another in direct opposition. Even so, those who are standing on the Earth could not be prevented from seeing both [divinities] because it is the Earth's curvatures on which they are standing. These curvatures do not im-

13. The logical necessity here is again (cf. II.2.19–30, with II.2 n. 9) implicitly based on the Stoic fifth undemonstrated argument.

14. Cf. II.2.27–28.

15. For such an eclipse reportedly observed in the west by Hipparchus see Plin. *NH* 2.57.

pede people standing on them from seeing both the bodies above the horizon, although they will obstruct the divinities when they are in direct opposition to one another. Thus while [the Sun and Moon] will not face one another, *we* will not be prevented from seeing both of them because we are standing on the Earth's curvatures.[16] The latter obstruct those bodies that are in low areas at the horizon, whereas the curvatures on which we are stationed are more elevated.[17]

139: That was how earlier scientists solved the problem adduced here, but their position may not be sound. This is because while our line of sight might be affected in this way at an elevation, since the horizon becomes conical when we are elevated into the air far above the Earth,[18] this is no longer the case when we are located *on* the Earth. For despite the existence of curvatures on which we are located, our line of sight is eliminated by the size of the Earth.[19] So it must not be stated, or believed to be at all possible, that a lunar eclipse occurs when both [Sun and Moon] are observed above the horizon by us while we are standing on the Earth.

149: Instead, we must confront [proponents of paradoxical eclipses] initially by claiming that this theory is fabricated by certain people who wish to impose a problem on the astronomers and philosophers who are engaged with these matters. For numerous lunar eclipses have occurred, both total and partial, and have all been recorded, yet nobody is reported

16. Such a sight line would mean an Earth no longer discountable ("a point") in relation to the distance of the Sun (as argued in I.8). Either the cosmos would be smaller, or the Earth larger. See I.8 n. 34.

17. This observer is at ground level, but has a "conical" horizon (line 142), i.e., one of more than 180°. The Sun and Moon are thus in the "low areas" beneath this *enlarged* horizon, and the Earth affects observation as though it were a mound over which we look at bodies on either side of it.

18. Curvatures are inherent to a spherical Earth (I.1.247 and 250; I.3.17 and 30; I.5.116 and 120), but visible only from an elevated position (I.8.138–139) due to the Earth's size.

19. For a ground-level observer the sight line literally "disappears into" *(enaphanizetai)* the distance, and the Earth appears to be flat (see I.5.11–13); i.e., we have a horizon of 180°, even though the Earth is spherical.

as having recorded this type of eclipse, at least up to our lifetime—no Chaldean, Egyptian, or other scientist or philosopher. The claim is just a fabrication. Second, if the Moon were eclipsed in any other way than by falling into the shadow of the Earth, it could also be eclipsed when *not* at full Moon, that is, when it advances a large or small distance away from the Sun, and eclipsed again after full Moon when it approaches the Sun and is waning. But in fact, although it undergoes numerous eclipses (eclipses being frequent enough), it has never been eclipsed except at full Moon, that is, when in opposition to the Sun—in fact only when it is possible for it to encounter the shadow of the Earth. Certainly all its eclipses are predicted by people who construct astronomical tables, because they know that, whenever coincidence occurs, it is at full Moon that the Moon is detected either totally or partially below the exact middle of the zodiacal band, and that in this way it effects either partial or total eclipses. It is therefore impossible for a lunar eclipse to occur when *both* luminaries are seen above the horizon.

168: Since there are by nature a wide variety of conditions that affect the air, it would not be impossible for us to encounter an image of the Sun[20] as not yet having set after it had already set (that is, after it was below the horizon). The cause[21] could be a rather dense cloud present in the west that is illuminated by the rays of the Sun and sends out an image of the Sun to us.[22] Or it could be the occurrence of a counter-Sun,

20. This "image" *(phantasia)* is a genuine illusion, unlike cases of visible objects projecting illusory appearances (e.g., I.8.21 and 159–160), or the cases of the Sun's appearance cited in II.1.

21. The multiple explanations that follow, which may be Posidonian, are incompatible with one another, like some sets of explanations in Epicurean physics (see Wasserstein [1978]). Cf. I.4.90–109 where, by contrast, Posidonius is reported as entertaining multiple, though complementary, explanations.

22. On this phenomenon (known as parhelion, or mock Sun) see Kidd *Comm.* 467–470 (on Posid. F121EK) and D. Kidd (1997) 476–477 (on Arat. *Phaen.* 881). Clouds can be permeated by the Sun's rays (II.4.95–97 and 103–104), but also acquire moisture from the atmosphere at the horizon (line 175 below; cf. II.1.29–30), and so can reflect light (see II.4.35–36).

since many things like that appear in the air, and particularly around Pontus.[23] But the ray that flows out from the eyes could also be refracted on encountering air that is damp and moist, and encounter the Sun after it is already concealed below the horizon.[24]

178: Something similar to the latter is also observed happening in our ordinary experience. For example,[25] if a gold ring is placed in a cup, or in some other vessel, then if the vessel is empty, the object placed within is not visible at an appropriate distance[26] because the visual pneuma runs unimpeded down from the brim of the vessel in a straight line. But when the vessel is filled with enough water to become level with the brim, then from the same distance the ring lying within the vessel is visible. This is because the visual pneuma no longer runs [straight] down from the brim, but comes into contact with the water that has filled [the vessel],[27] and is thus refracted, goes to the bottom of the vessel, and encounters the ring.[28] Something similar could, then, occur with damp and sodden air too, so that when the ray from the eye is refracted and bends below the horizon,

23. For a counter-Sun (anthelion), sometimes confused with parhelion, occurring in the eastern sky, in the area of Pontus, see Anaxagoras at DK 59A86.

24. On atmospheric conditions affecting astronomical observations, with reference to this passage, see Lloyd (1982) 134–135, and cf. Ptol. *Opt.* 5.23–26 (tr. Smith [1996] 238–240). Cf. also II.1 n. 11.

25. For this example see also Archim. at Olymp. *In meteor.* 211.18–23 (= Archim. Fr. 18; cf. Fr. 17), Sen. *NQ* 1.6.5, Ptol. *Opt.* 5.5 (tr. Smith [1996] 230–231), and Damian. *Opt.* 14.3–6 (ed. Schöne [1897]). Cf. Eucl. *Catoptr.* 286.17–19 for the general principle involved.

26. This distance is "appropriate" (*summetron;* cf. II.4 n. 32) in the sense that eye and object are at a distance and angle that ensures the object's visibility. For this same general sense see Alex. Aphr. *De an.* 41.17–19, Sext. Emp. *AM* 7.188 and 438, and cf. Sedley (1976) 49 with n. 90.

27. "[Level] to the brim" (*κατὰ τὰ χείλη*, line 185) is the manuscript reading printed in Todd's edition. It is omitted here as a gratuitous iteration of the same phrase in the preceding line. Since the vessel is already said to be full to the brim (lines 182–183), no additional reference to this fact is needed.

28. The visual cone (see II.1.57–70 and II.5.107–141), also relevant to refraction, is not mentioned.

it encounters a Sun that has already set, so that an image of it is engendered as still being above the horizon. Perhaps something else much like this could also on occasion produce an image in us of the two [heavenly] bodies being above the horizon after the Sun has already set. Still, that the Moon is eclipsed *only* by falling into the shadow of the Earth is a cognitively reliable[29] [conclusion] derived from the phenomena. That, then, is enough on the eclipse [of the Moon].

29. *enarges:* that is, not just visually but cognitively reliable, and applied to a process of reasoning. See Introduction 10, and II.1 n. 61.

CHAPTER SEVEN[1]

1: The Moon is said to move a greater distance than do the other planets toward each [side] of the circle through the middle of the zodiacal constellations; next in order is Venus, which goes 5 degrees to each [side] in its chosen motion, then Mercury (up to 4 degrees),[2] Mars and Jupiter (up to 2½ degrees), [and] Saturn (up to 1 degree on each side).[3]

5: Mercury and Venus do not move to every [angular] distance from the Sun, but Mercury [moves] 20 degrees at most, Venus 50 degrees at most; the remaining three, just like the Moon, move to every [angular] distance from the Sun.[4]

8: Mercury effects [superior] conjunction with the Sun in 116 days,

1. Since this chapter offers no rationale for the data presented, and since lines 11–14 could follow II.6 without any interruption in thought, lines 1–10 may be an interpolation.

2. In the list of planets at I.2.20–42, Mercury, not Venus, is located just above the Moon, another reason perhaps (see preceding note) for regarding this material as interpolated.

3. Neugebauer (1975) 1014–1016 analyzes the evidence in Ptolemy's *Handy Tables* for extremal latitudes, and compares it to the values given in the *Almagest*.

4. Neugebauer (1975) 804–805 catalogues ancient evidence on the maximum elongation of the inner planets.

when the latter comes in between it [and the Earth]; Venus resumes the same position in relation to the Sun in 584 days, Mars in 780 days, Jupiter in 398, Saturn in 378.[5]

11: That will be as far as our discussion of these [matters] will go, at least for the present.[6] These [two] lecture courses[7] do not comprise the writer's actual doctrines, but have been amassed from certain treatises, earlier as well as more recent ones, with most of the statements taken from Posidonius' [works].[8]

5. The interval in which a planet returns to the same position in relation to the Sun (e.g., conjunction) is known as its synodic period. Neugebauer (1975) 782–785 catalogues ancient evidence on planetary periods, and notes (785) that "beyond the Babylonian parameters only the synodic periods listed in Cleomedes II.7 are astronomically meaningful." See also Neugebauer (1975) 965.

6. For evidence of a forthcoming course see I.1.94–95, 173–174 and 191–192.

7. The "lecture courses" *(skholai)* are the sets of lectures that seem to have comprised the two books of the *Caelestia;* cf. II.2.7 where "the first of the *skholika*" refers to the whole of Book I.

8. This typical disclaimer (cf. also I.8.161–162 above; see Whittaker [1987] 102 with n. 77) should not be deleted as a gloss; see *Caelestia* ed. Todd *Praef.* xviii.

Figures

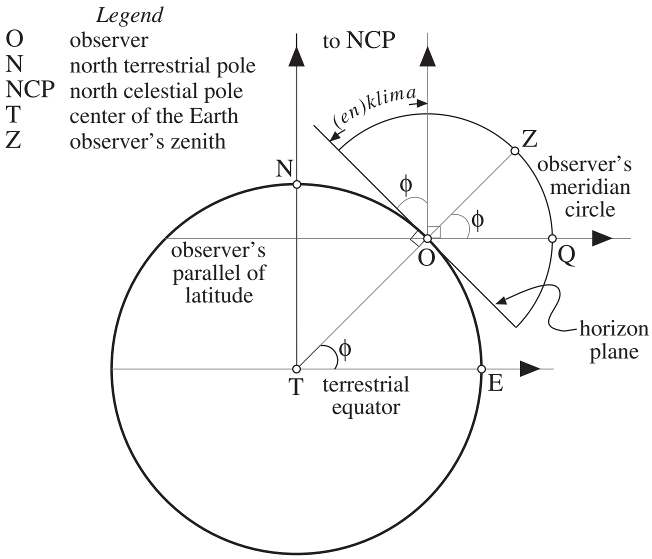


Figure 1. The *(en)klima* (ϕ) of the north celestial pole for an observer in the northern hemisphere (I.1.176)

ϕ is equal to angle ZOQ which is in turn equal to angle OTE, the observer's latitude.

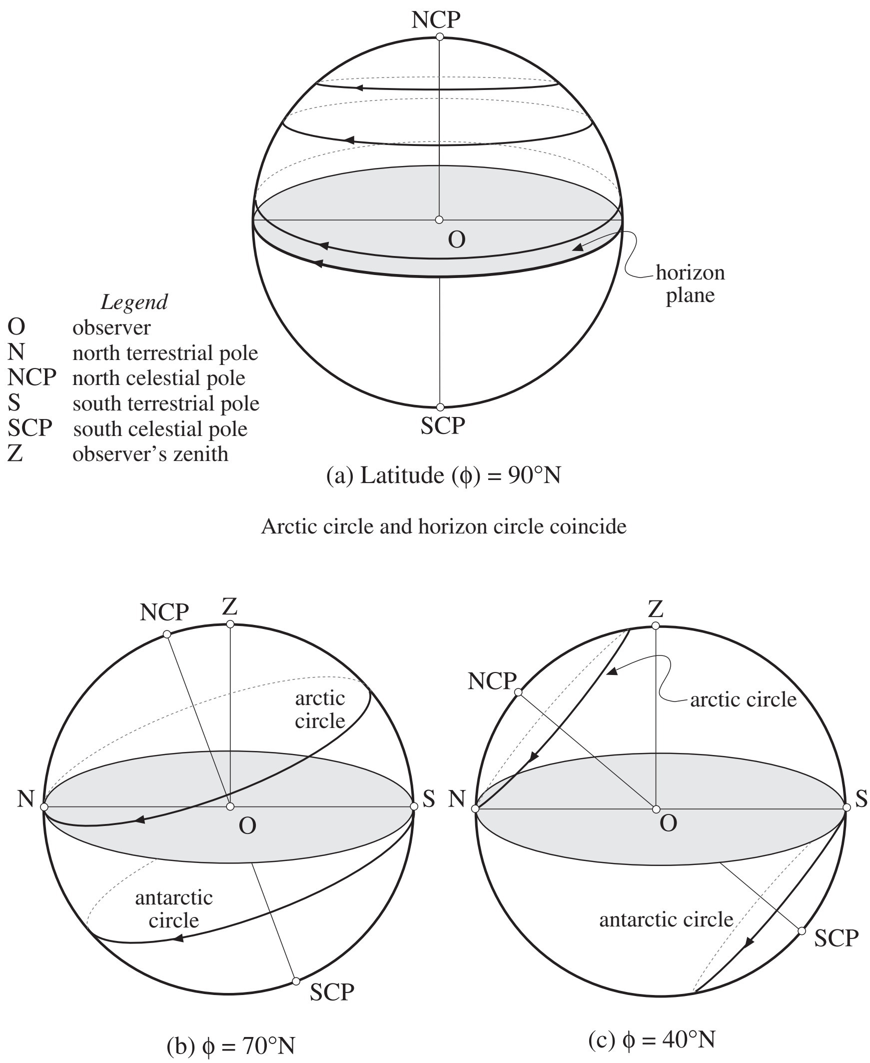


Figure 2(a)–(c). The variation of the arctic circle with the observer's latitude (I.1.193–201)

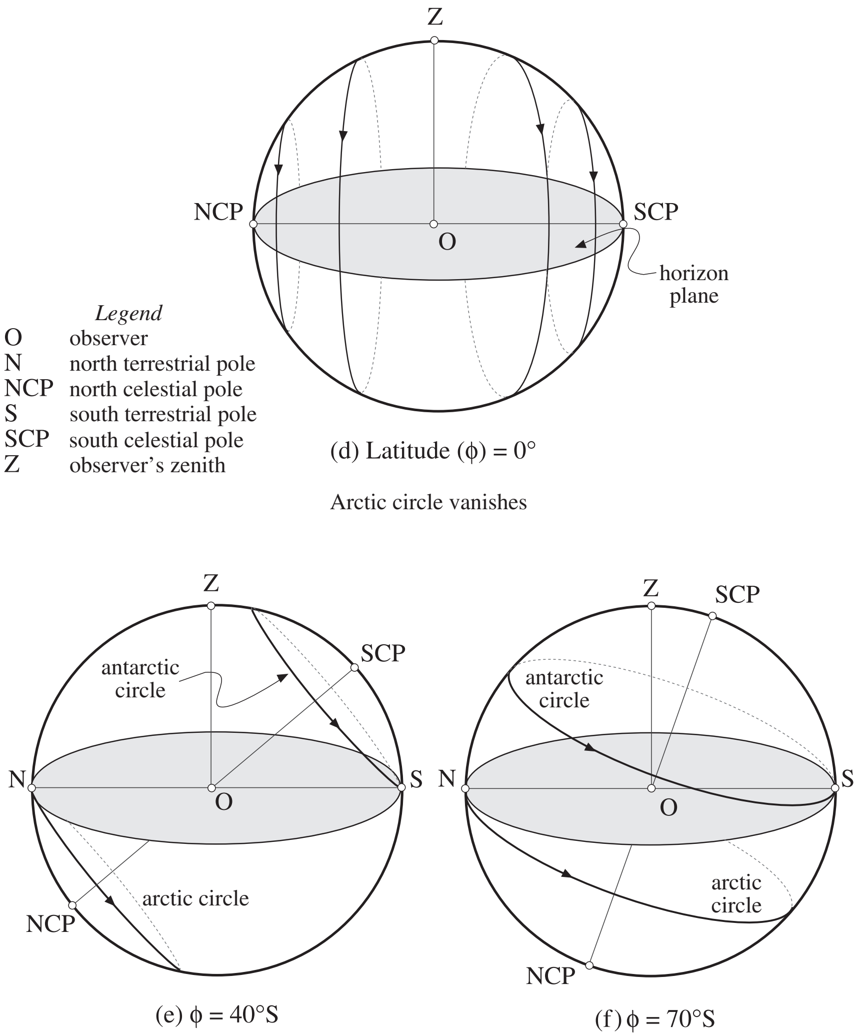


Figure 2(d)–(f). The variation of the arctic circle with the observer's latitude (I.1.193–201)

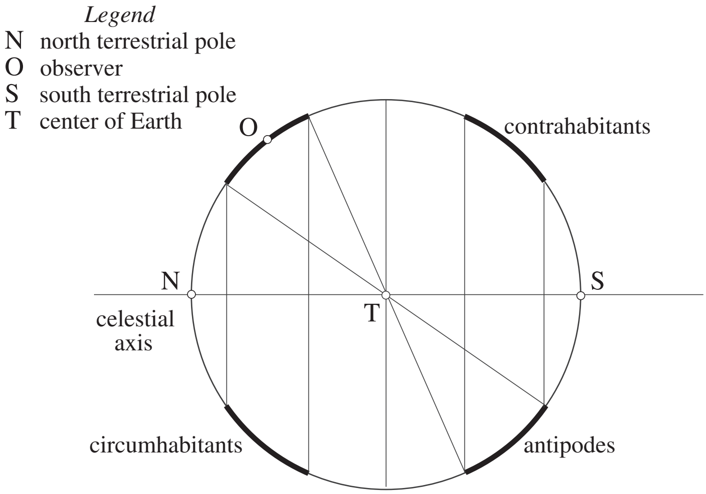
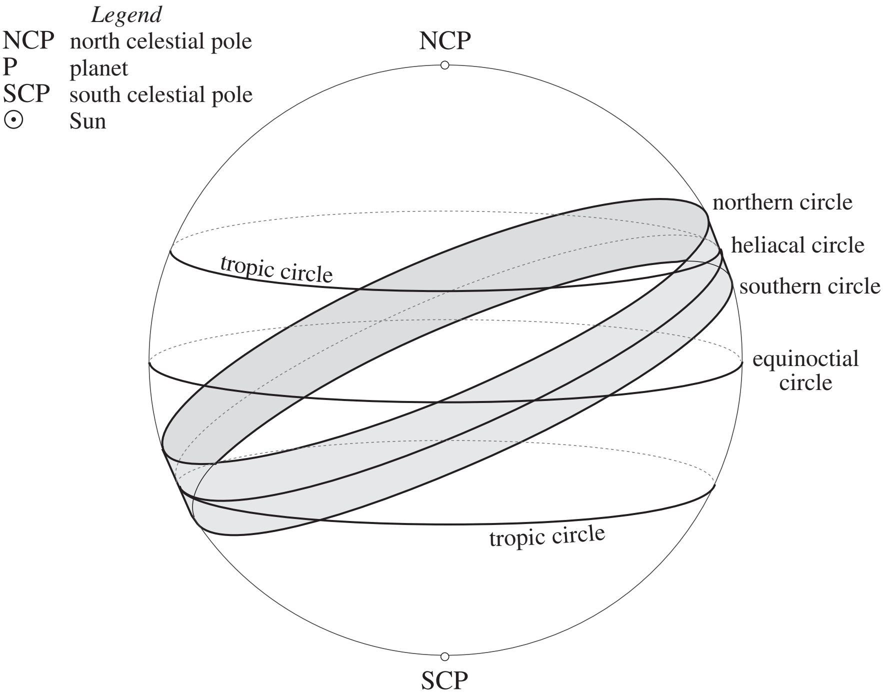
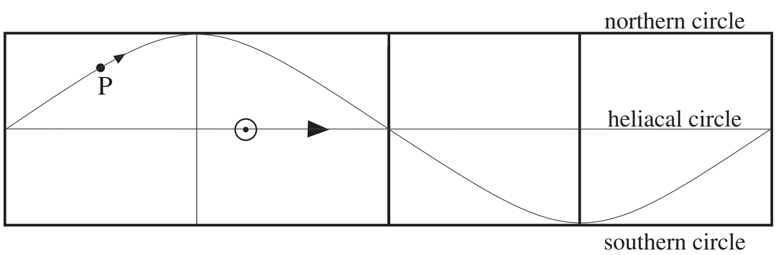


Figure 3. Cross-section of the Earth showing the locations of the inhabitants of the temperate zones (I.1.209–234)

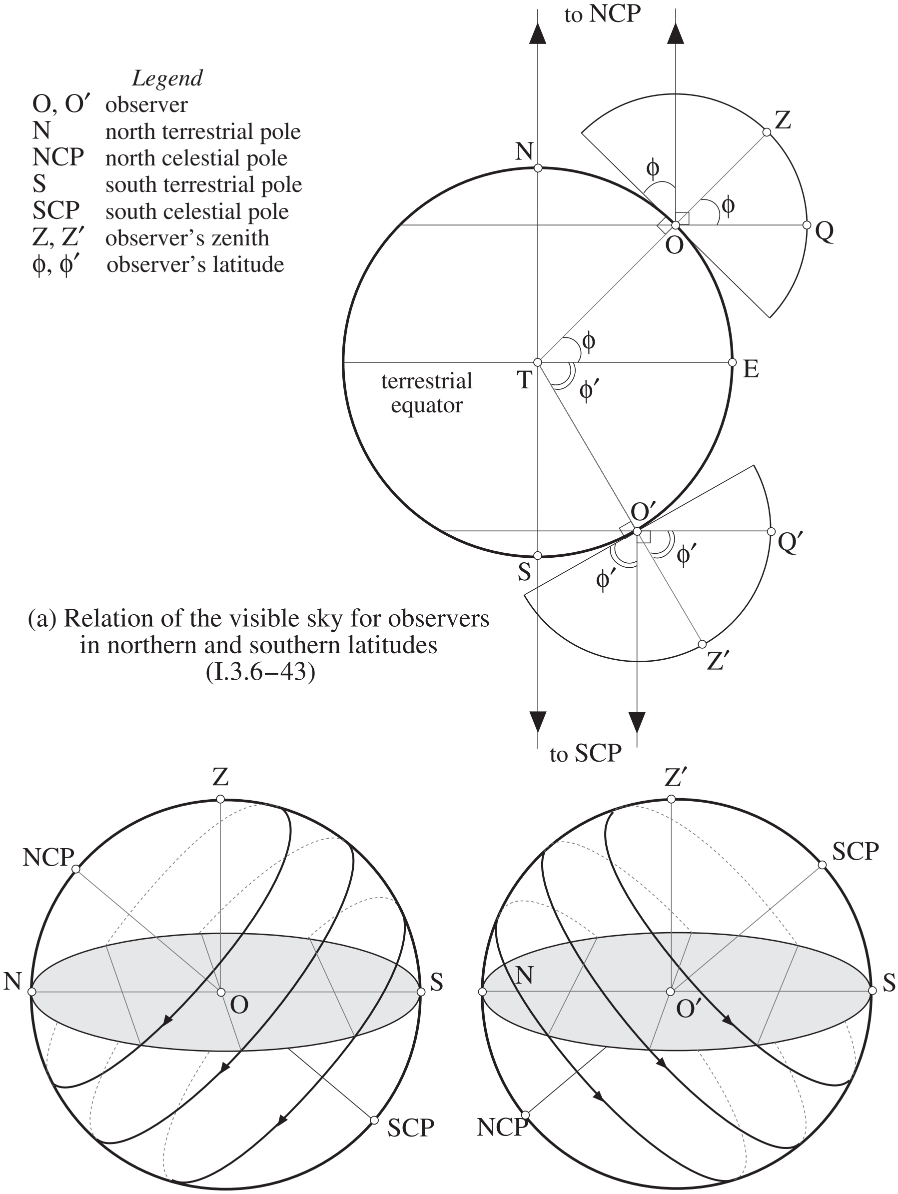


(a) The zodiacal band or zodiac
(I.2.43–59)



(b) Planetary motion in the zodiacal band (shown laid out flat)
(I.2.60–72)

Figure 4

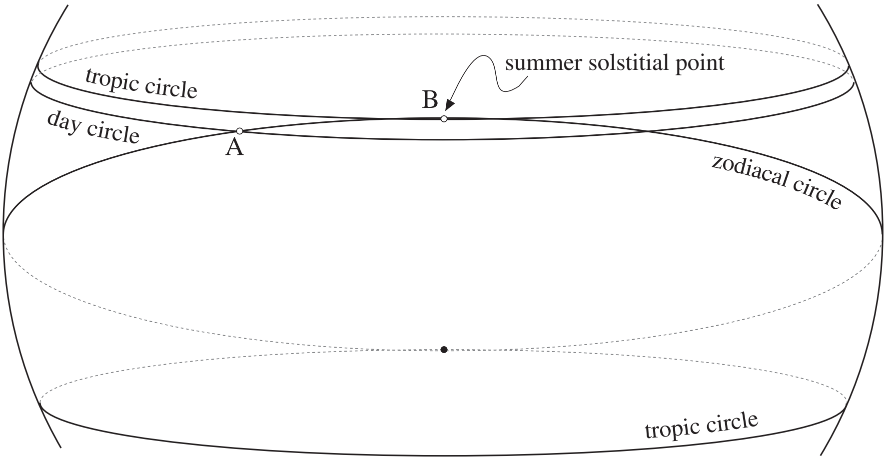


(a) Relation of the visible sky for observers in northern and southern latitudes (I.3.6–43)

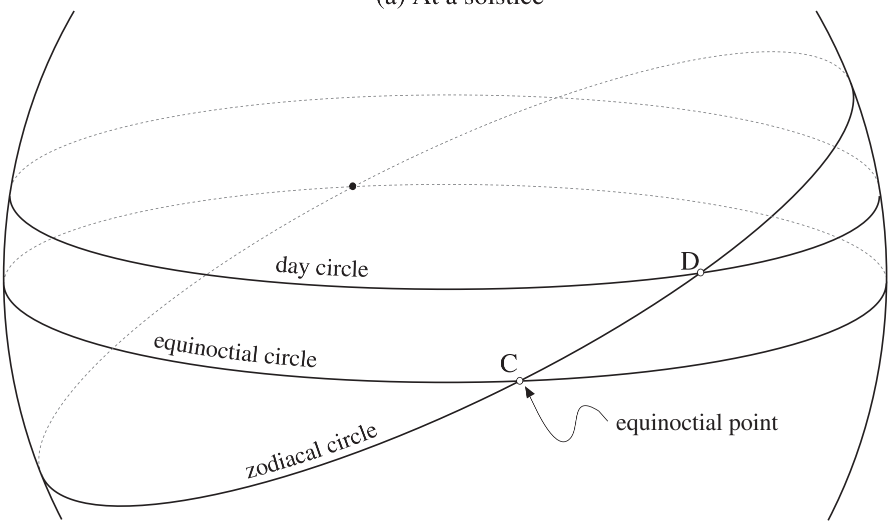
(b) Latitude (ϕ) = 40°N (I.3.54–68)

(c) ϕ = 40°S (I.3.69–75)

Figure 5. The interrelation of the equinoctial and solstitial circles for observers at northern and southern latitudes



(a) At a solstice



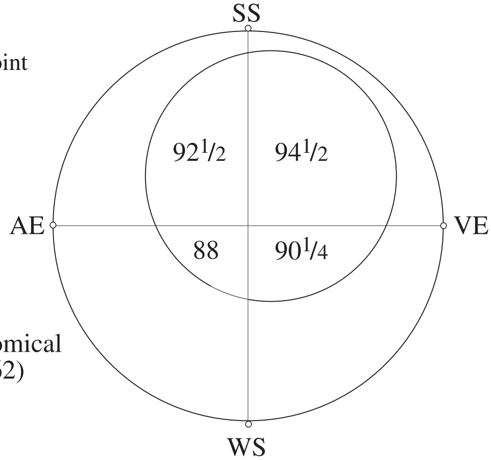
(b) At an equinox

Figure 6. Equal arcs (AB, CD) of the zodiacal circle and the varying distance between the corresponding day circles at the solstices and equinoxes (I.4.30–43)

The zodiacal circle is the trace of the heliacal circle on the zodiacal band and is itself sometimes called the heliacal circle.

Legend

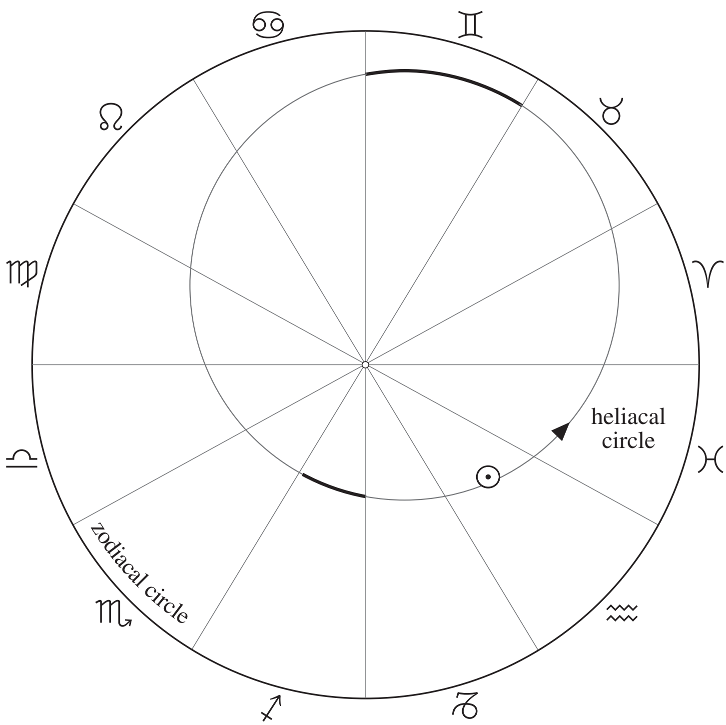
AE autumnal equinoctial point
SS summer solstitial point
VE vernal equinoctial point
WS winter solstitial point



(a) The lengths of the astronomical seasons in days (I.4.44–62)

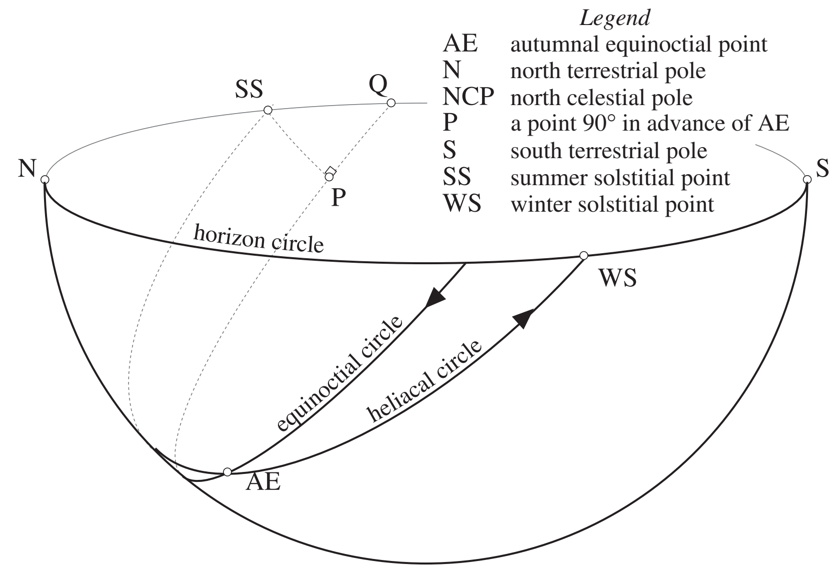
Legend

☉ Sun
♈ Aries
♉ Taurus
♊ Gemini
♋ Cancer
♌ Leo
♍ Virgo
♎ Libra
♏ Scorpio
♐ Sagittarius
♑ Capricorn
♒ Aquarius
♓ Pisces

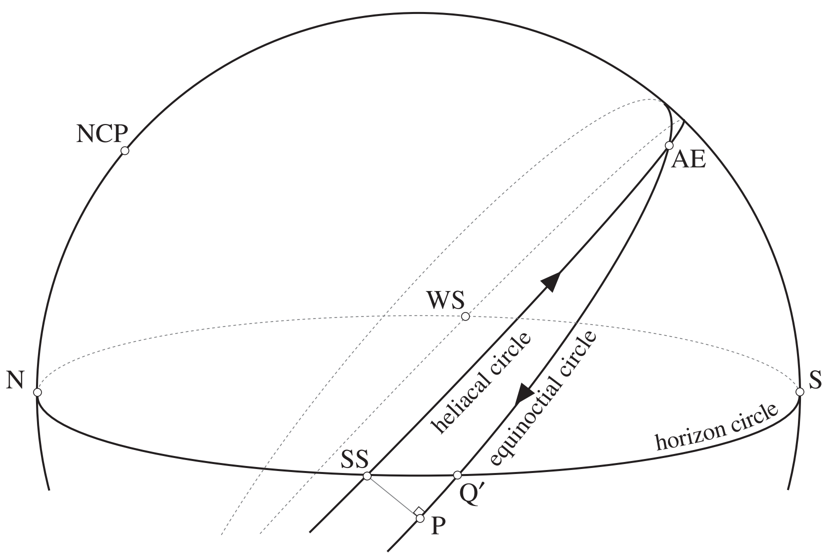


(b) The eccentricity of the heliacal circle relative to the zodiacal circle (I.4.62–71)

Figure 7



(a) The arc from SS to AE rises in the same time as the arc from Q to AE.



(b) The arc from SS to AE sets in the same time as the arc from Q′ to AE.

Figure 8. The summer signs (on the arc SS to AE) rise more slowly than they set (I.4.80–86)

The arc from Q to AE is longer than the arc from Q′ to AE.

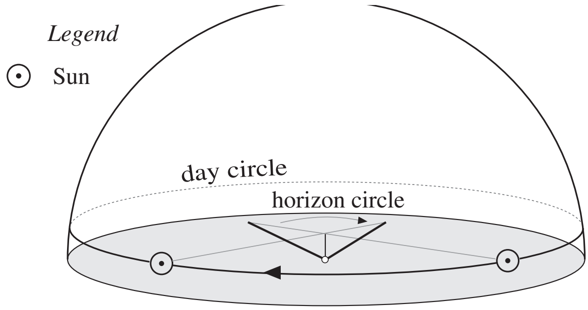


Figure 9(a). Inhabitants of the Earth encircled by shadow
(I.4.133–139)

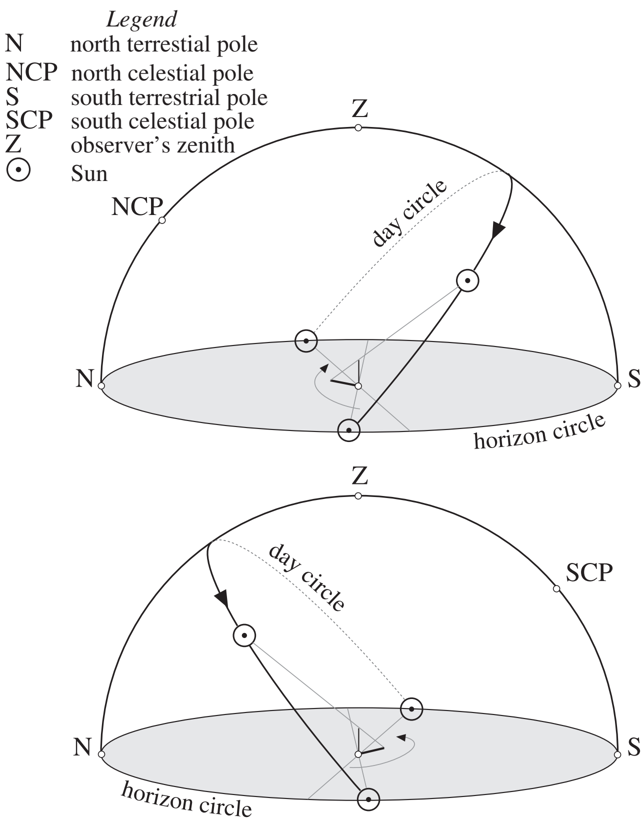


Figure 9(b). Inhabitants of the Earth shadowed unidirectionally
(I.4.139–143)

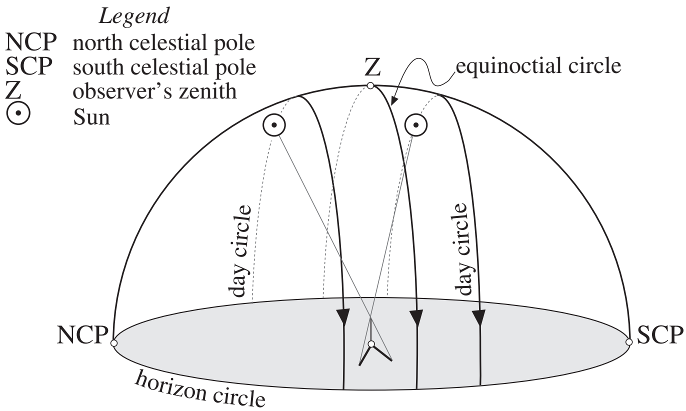
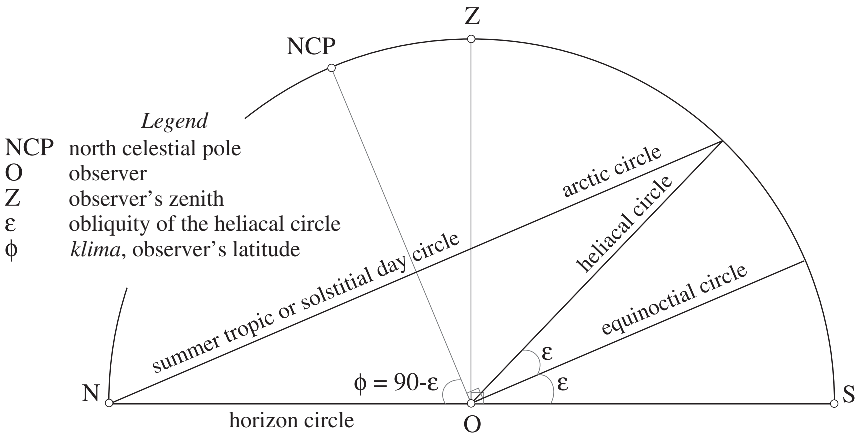
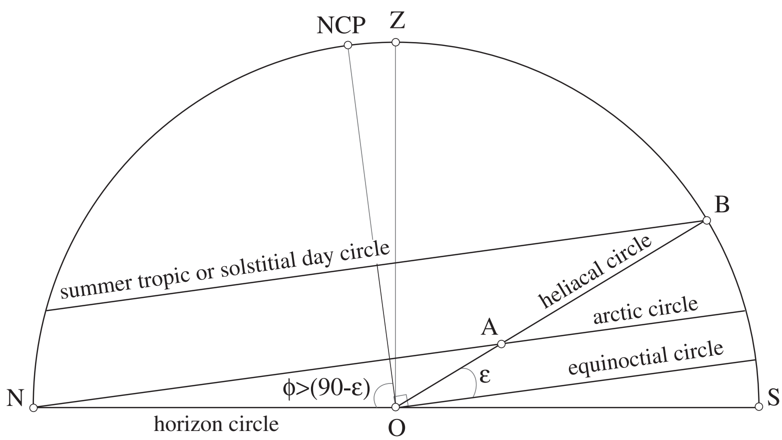


Figure 9(c). Inhabitants of the Earth shadowed bidirectionally (I.4.143–146)



(a) Side-view of the configuration of the heavens for an observer where the arctic circle and the summer tropic or solstitial day circle coincide (I.4.208–210)



(b) Side-view of the configuration of the heavens for an observer to the north of Thule (I.4.218–219)

There will be continuous daylight for twice as long as it takes the Sun to travel from A to B.

Figure 10

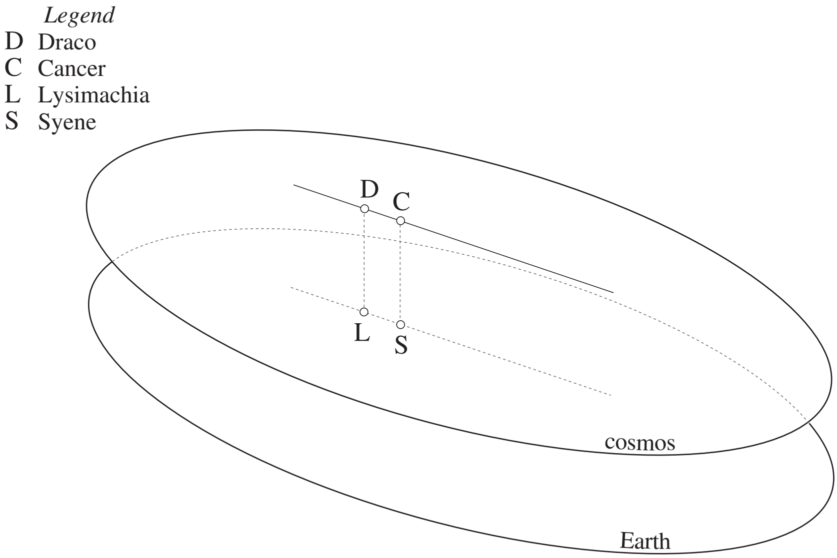


Figure 11. The size of the cosmos, assuming that both it and the Earth are flat and parallel (I.5.57–75)

The distance from L to S is 20,000 stades, and the “arc” from D to C is $^{1}/_{15}$ of the cosmos’ “circumference.”

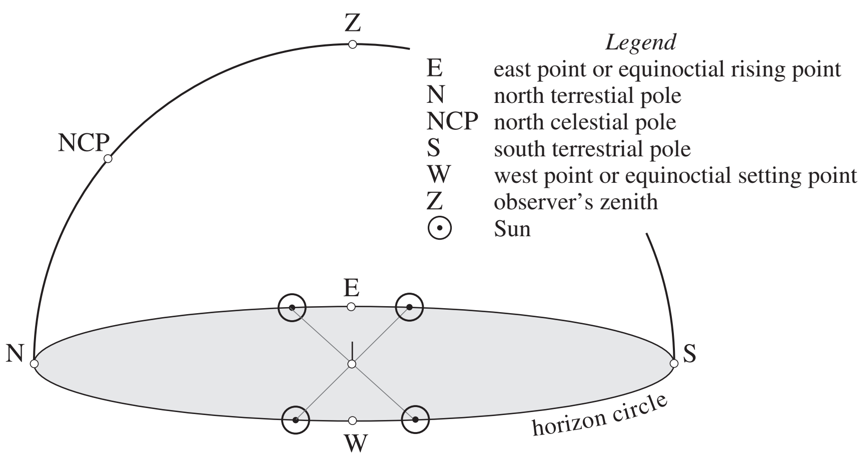


Figure 12. The chiasmus defined by a gnomon’s shadow when the Sun is at the summer and winter solstitial points (I.6.26–31)

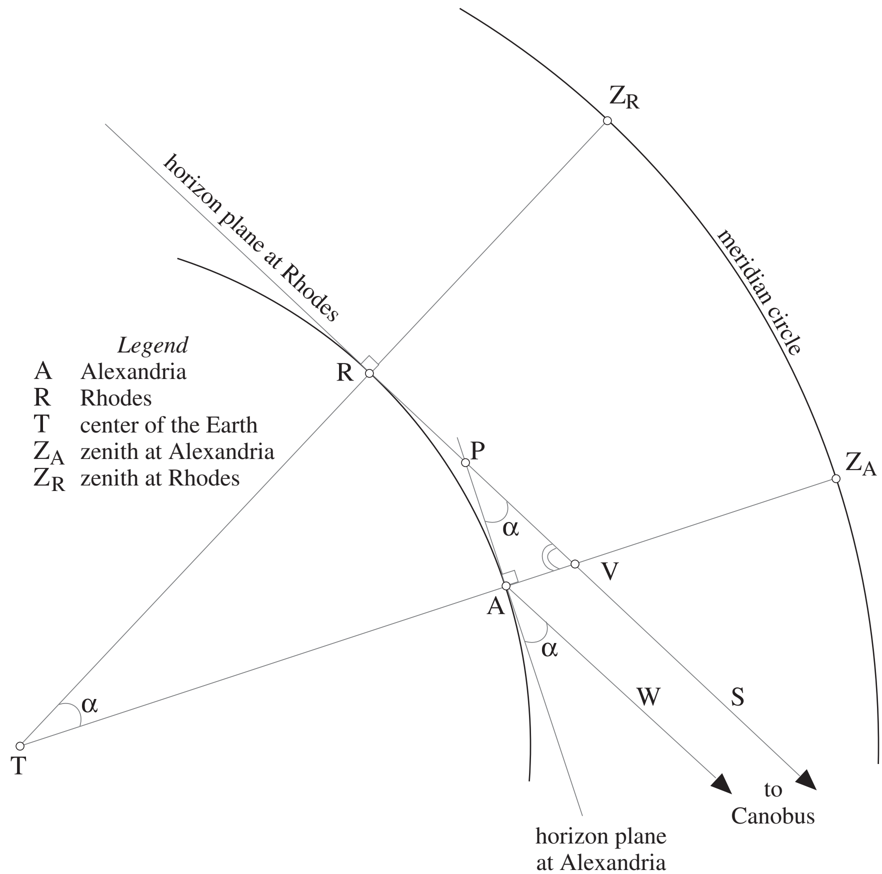


Figure 13. Posidonius' calculation of the size of the Earth (I.7.8–47)

The elevation of Canobus above the horizon at Alexandria (angle α) is 1/48 of a circle and equal to the arc from the zenith at Rhodes to the zenith at Alexandria. Since the arc from Rhodes to Alexandria is 5,000 stades long, the circumference of the Earth is 240,000 stades.

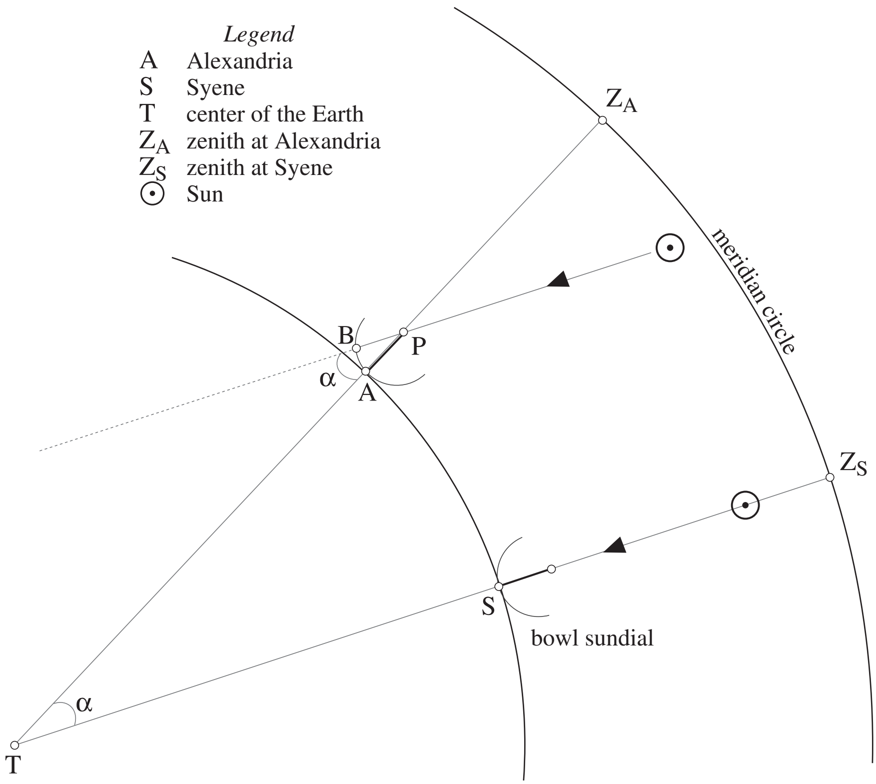


Figure 14. Eratosthenes' calculation of the size of the Earth (I.7.49–110)

Since angle BPA equals angle ATS and arc BA is 1/50 of a circle, arc AS is also 1/50 of a circle. Thus, given that the arc from Alexandria to Syene is 5,000 stades long, the circumference of the Earth is 250,000 stades.

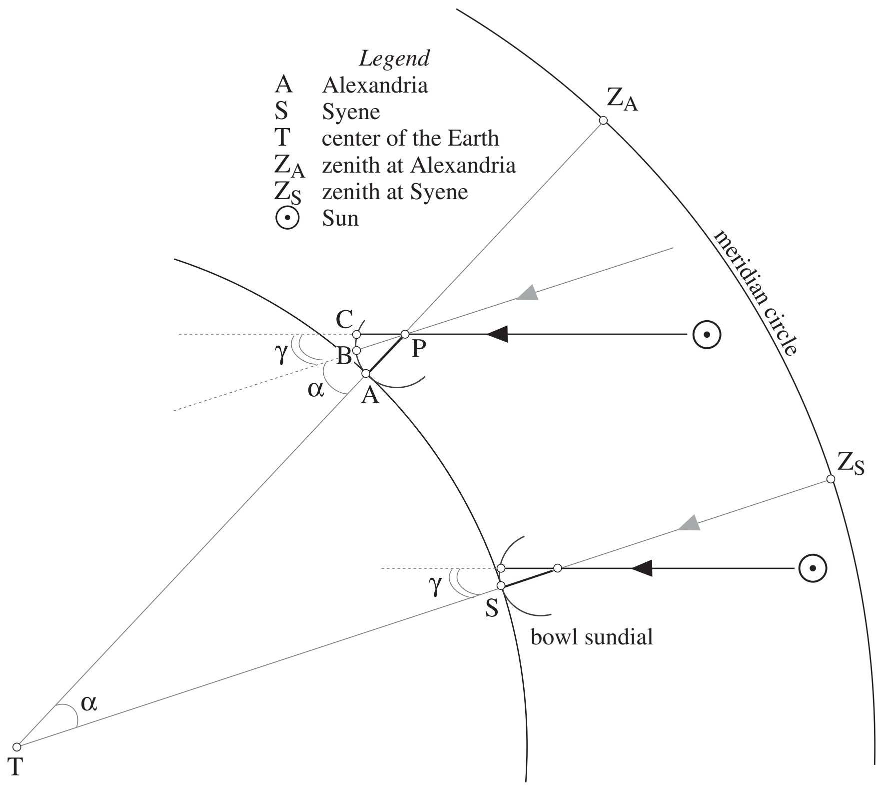


Figure 15. Eratosthenes' calculation of the size of the Earth adapted for the Sun at winter solstice (I.7.111–118)

Angle CPB = γ. Angle CPA – angle CPB = angle BPA. But angle BPA = angle ATS. So, since arc BA (= arc CA – arc CB) is $^1/_{50}$ of a circle, arc AS is also $^1/_{50}$ of a circle. Thus, given that the arc from Alexandria to Syene is 5,000 stades long, the circumference of the Earth is 250,000 stades.

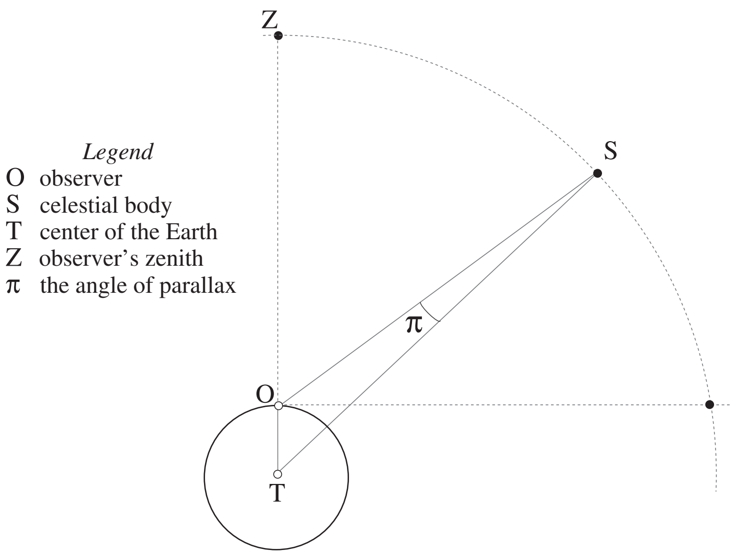


Figure 16. The parallax of S for an observer at O (I.8)

The parallax of S is greatest when it is at the observer's horizon and vanishes when it is at his zenith. If S is suitably distant from O, its parallax becomes negligible for all positions of S. This means that the observation of S from O is effectively the same as the observation of S from T, i.e., that the Earth is virtually a point in relation to the distance of S.

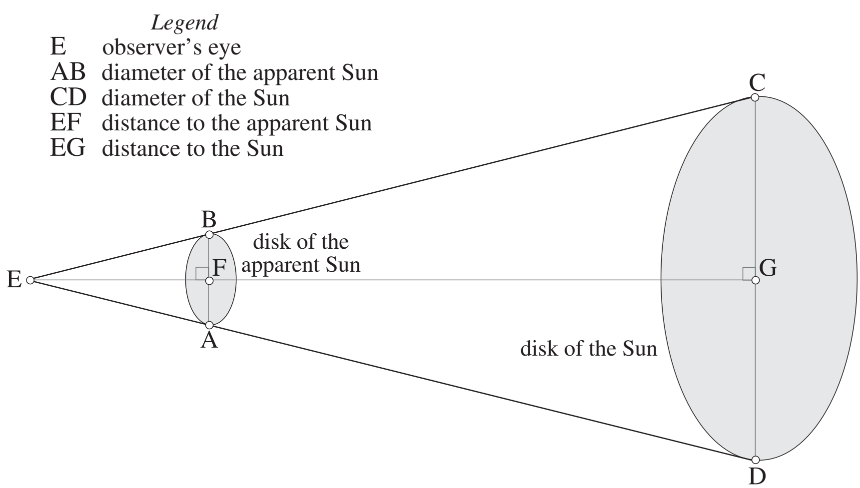


Figure 17. The real and apparent visual cones defined by the Sun (II.1.57–75)

Since triangle AEB is similar to triangle DEC, then EF:EG :: AB:DC

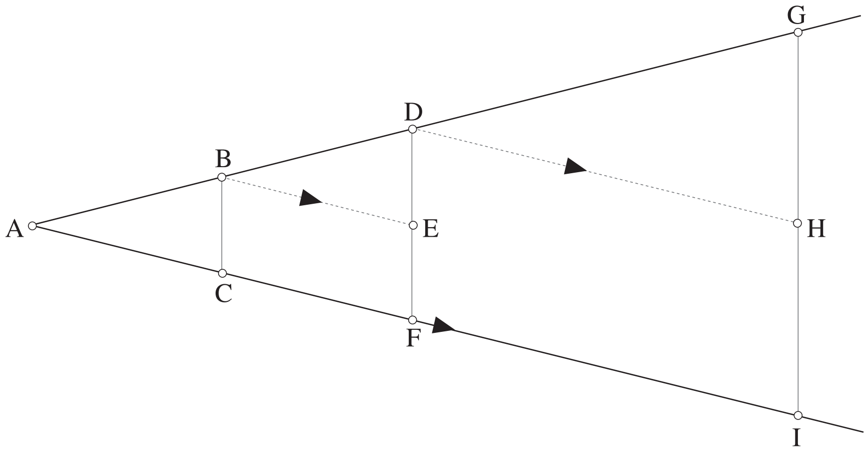


Figure 18
(II.1.243–249)

Isosceles triangle ADF is similar to isosceles triangle ABC and AD = 2AB. Therefore, AD:AB :: DF:BC :: 2:1. Similarly, isoceles triangle AGI is similar to isoceles triangle ABC and AG = 2AD = 4AB. Therefore, AG:AB :: GI:BC :: 4:1.

Legend

E	observer's eye
AC	width of the island
DG	diameter of the solar disk
EB	distance to the island
EF	distance to the Sun

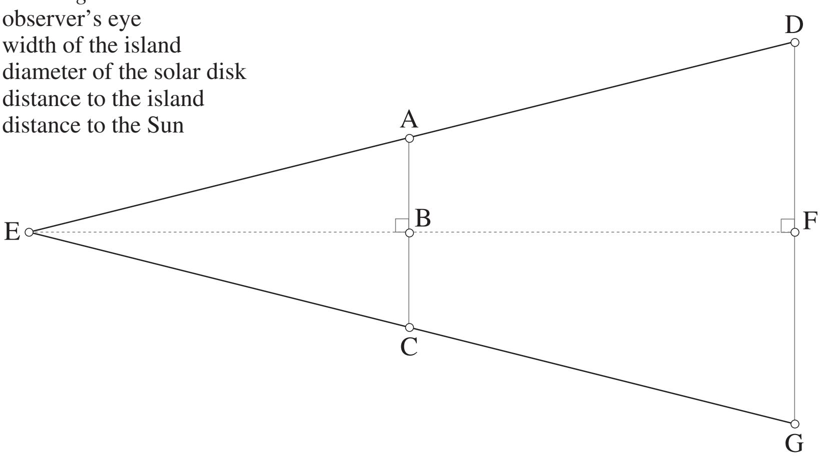


Figure 19
(II.1.249–268)

Triangle EDF is similar to triangle EAB and EF = 2EB. Therefore, EF:EB :: DF:AB :: 2:1. Since DF = FG and AB = BC, DG = 2AC.

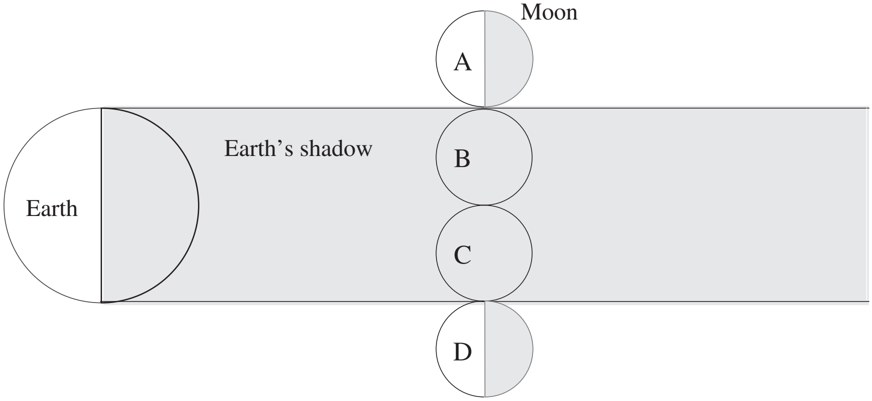


Figure 20
(II.1.286–294)

The time it takes the Moon to go from position A to position B is the same as the time it takes the Moon to go from position B to position C. So the Moon measures the Earth's shadow twice. If the Earth's shadow is cylindrical, then the diameter of the Moon is half of the Earth's diameter.

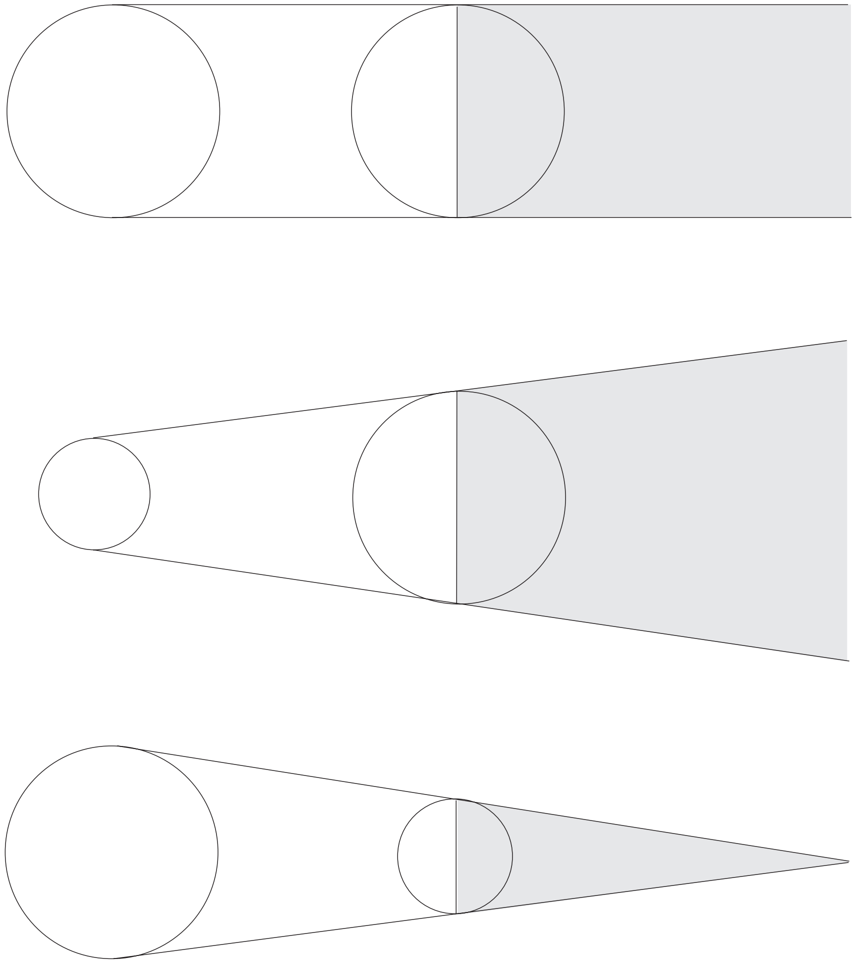


Figure 21. Types of shadow cast by a spherical body
when illuminated by a spherical body
(II.2.19–24)

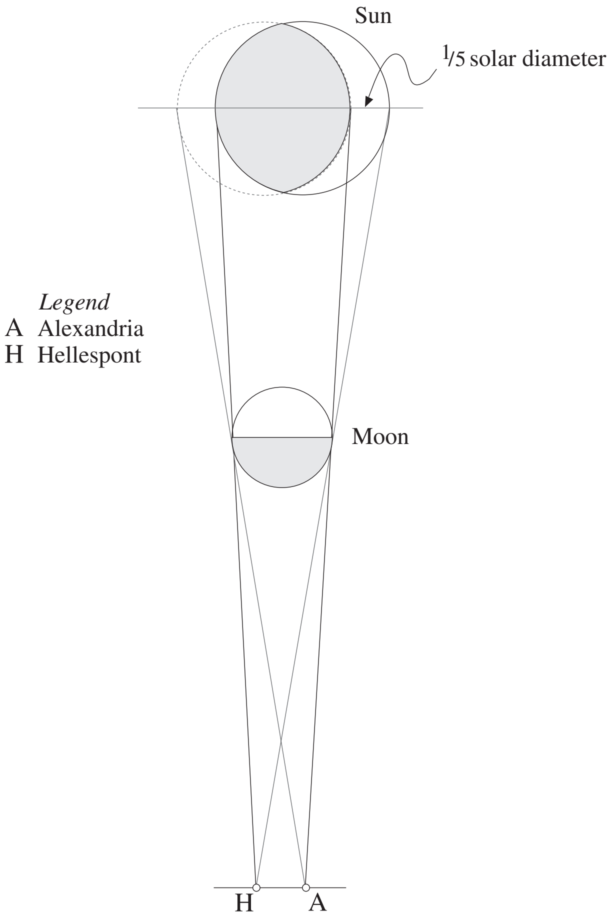


Figure 22. The solar eclipse as seen from the Hellespont and Alexandria
(following Neugebauer [1975] 1312, fig. 290)
(II.3.15–19)

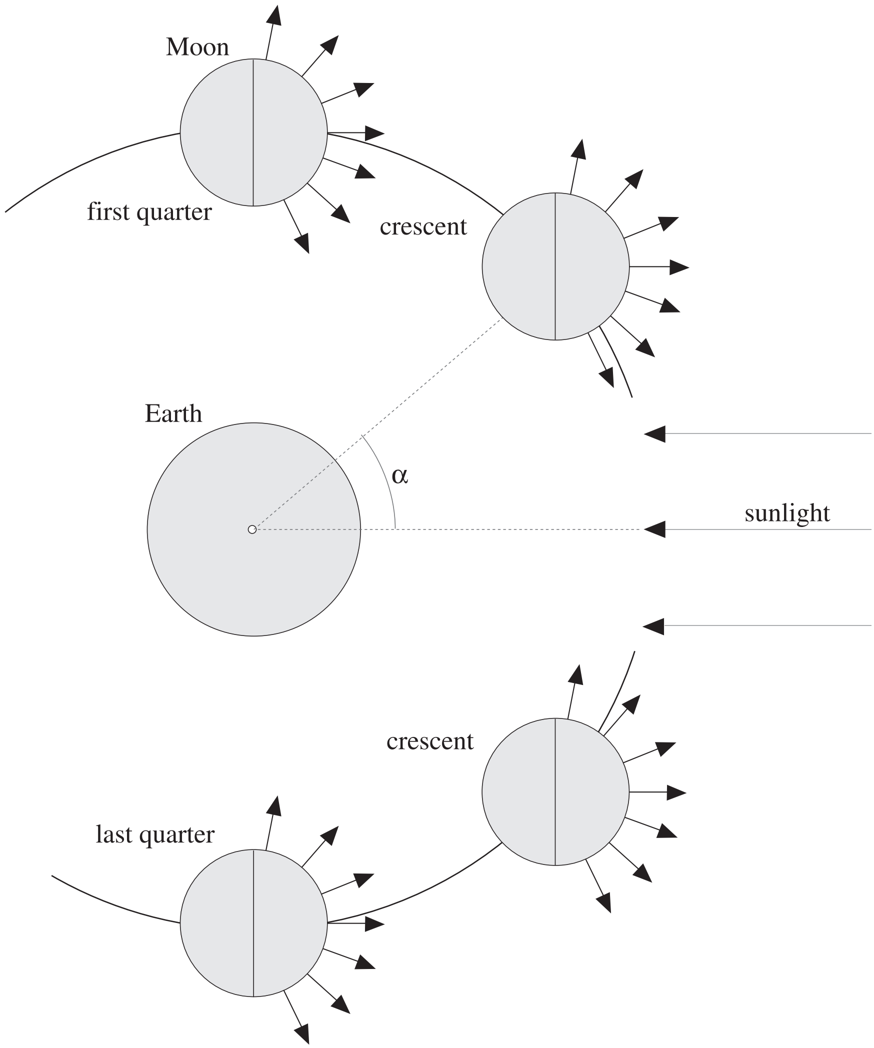


Figure 23. View from the pole of the Moon's orbit of the Earth and Moon in cross-section, showing the Moon at the crescent and the quarter as it reflects the Sun's light at "right angles," that is, radially (II.4.56–61)

According to Cleomedes, when angle α defined by the Moon, the Earth, and the Sun is 90° or less, no reflected light from the Moon reaches the Earth.

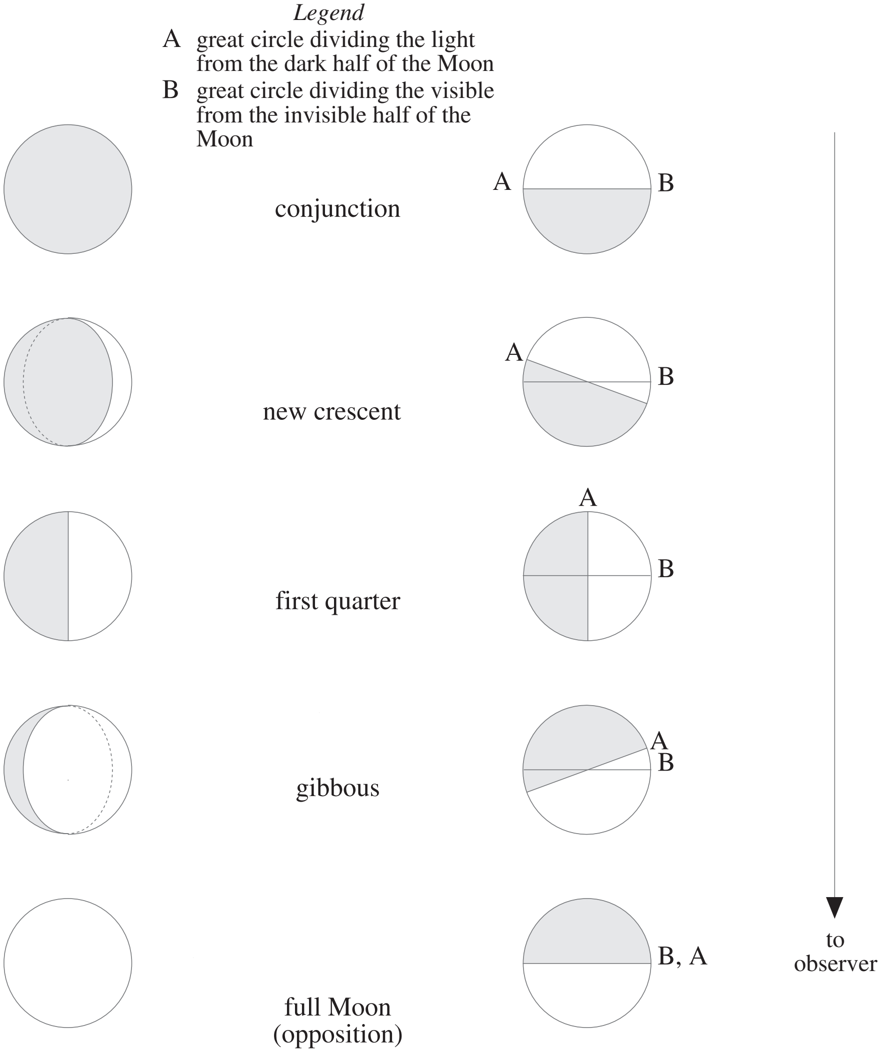


Figure 24(a). The phases of the Moon from conjunction to full Moon (II.5.41–80)

The great circles, A and B, are viewed from above the pole of the Moon.

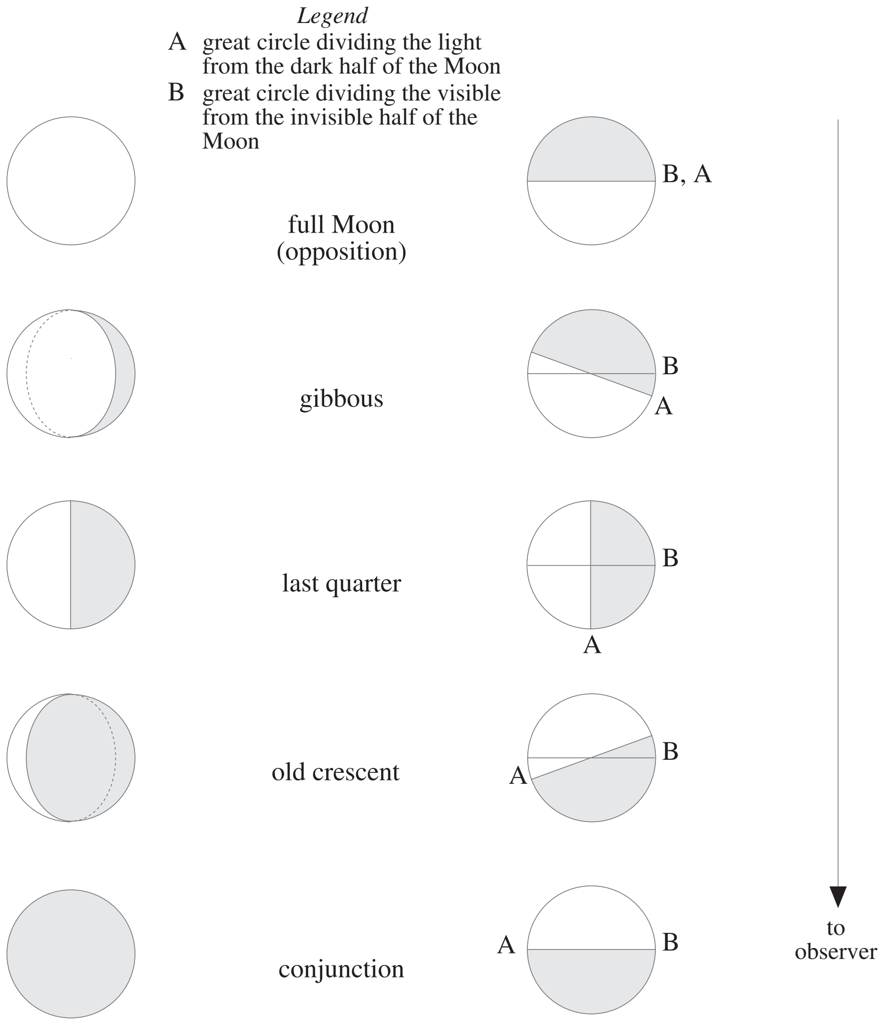


Figure 24(b). The phases of the Moon from full Moon to conjunction (II.5.41–80)

The great circles, A and B, are viewed from above the pole of the Moon.

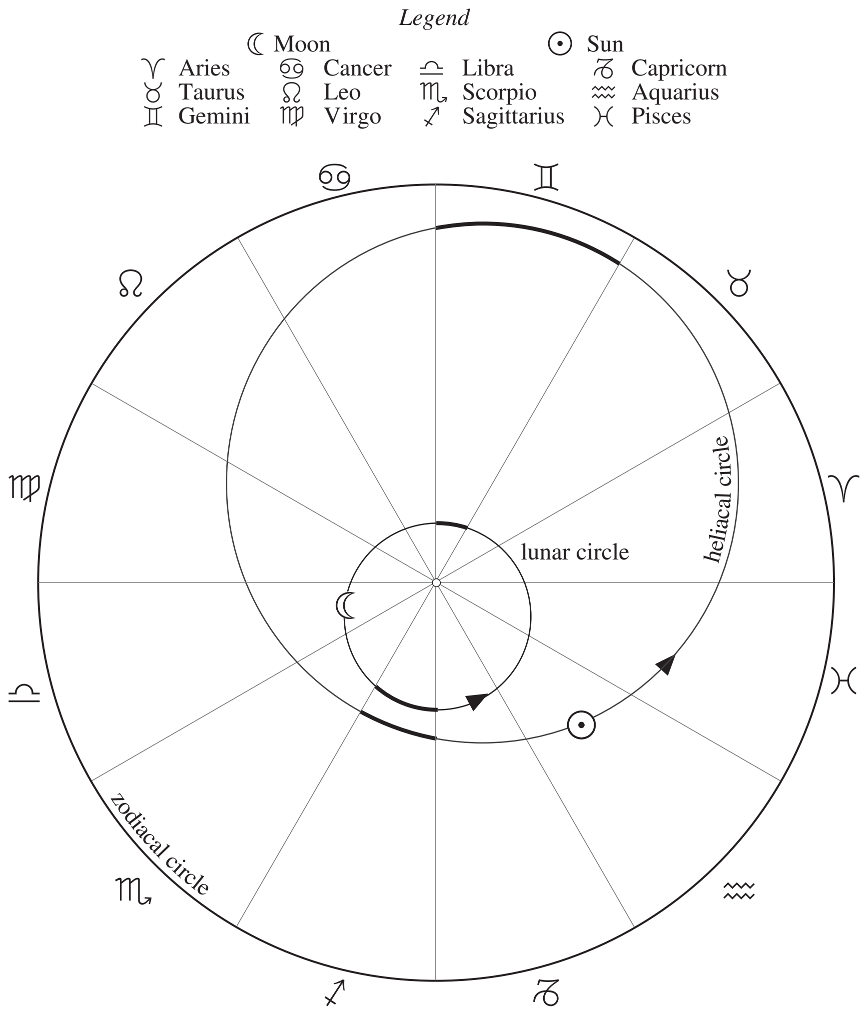


Figure 25. The variation in the length of the synodic month (II.5.102–132)

APPENDIX: POSIDONIUS ON PHYSICS AND ASTRONOMY

(Fragment 18EK[1])

In the Introduction we highlighted Posidonius F18EK to clarify Cleomedes' dependence on Posidonian principles both for the general structure of his treatise, and for its methodology. Our case is principally based on lines 5–32 and 39–49 of the text translated below. They develop a programmatic distinction between physical theory and astronomy with reference to their differing approaches to the same subject matter. Physical theory is founded on the intrinsic qualities of the material cosmos, while astronomy concerns itself with incidental properties accessible through observation, and makes calculations about them. This descriptive distinction is reinforced by the prescription (lines 30–32 with 39–49) that in the crucial area of the motion of the heavenly bodies, astronomy must derive from physical theory its account of what in the cosmos really is in motion and what is stationary.

Now F18EK is not a fragment, in the sense of an authentic segment of an original work. It is a report by the sixth-century A.D. Neoplatonist commentator Simplicius of a quotation by a late second-century A.D. Peripatetic commentator, Alexander, from an epitome of a Posidonian treatise made around two

1. The text, unless otherwise noted, is that in EK, the line numbers of which are also followed. For some modern translations see Heath (1913) 275–276, Edelstein (1936) 319–320, and Aujac (1975) 110–113; for commentary see Aujac (1975) 161–162 and Kidd *Comm.* 129–136.

centuries earlier by Geminus.[2] Material may therefore have been omitted and rearranged by the original epitomizer, and further adapted for report by the later writers. This process of transmission has undoubtedly contributed to the elliptical character of this text, and our notes to the translation will try to supply a context for its argument. One section of F18EK, however, needs some preliminary discussion, even though it does not bear directly on any Cleomedean material. This is a passage concerning planetary motion at lines 32–39, which we shall argue is not integral to the argument of this text, although it is an important commentary on some of its content. If its status is properly understood, then it may no longer be used, as it has previously been, as evidence for Posidonius' general position on the role of astronomy in relation to physical theory.

F18EK, we suggest, offers a coherent argument without lines 32–39, as can be seen from the link between the two sections that surround them. Thus lines 30–32 state that astronomers will introduce hypotheses (without reference to any specific subject matter) to save the phenomena, while at lines 39–42 we learn that such a dependence on hypotheses is why[3] Heraclides of Pontus (380s–ca. 310 B.C.) tried to explain the "unsmooth" *(anōmalos)*[4] motion of the Sun by claiming that the Earth moves while the Sun is stationary. The details of Heraclides' theory do not interest Posidonius, only the fact that it exemplifies the procedure of explaining phenomena by saving them through a hypothesis (see n. 35 below). That general procedure is recapitulated at lines 42–45 with reference to celestial motion, and a final comment (46–49) is made about the need for astronomers to derive from natural philosophers the principles that define the motions that are possible for heavenly bodies. In this sequence of reasoning *any given astronomer* (cf. n. 19 below) is envisaged as formulating a *single* hypothesis to explain the motion of the heavenly bodies on the basis of the phenomena, and then, as in Heraclides' case, becoming liable to having that hypothesis corrected as the price of not having started with principles supplied by natural philosophy.

2. This must be Geminus of Rhodes (first century B.C.), whose introduction to astronomy has been frequently cited in this study. Proclus *In Eucl. El. I* 38.1–42.8 (at Aujac [1975] 114–117) records a taxonomy of the sciences consistent with that of F18EK; see in particular 41.29–42.6 on astronomy. The view that the author of the introduction to astronomy was an earlier Geminus (Reinhardt [1921] 178–183) has not won wide acceptance.

3. Thus at line 39 below, διό ("that is why") has to introduce a specific instance of the general claim made at lines 30–32.

4. See n. 29 below.

Now lines 32–39 begin with "for example" (*οἷον*), yet offer no example of the use of a hypothesis to save the phenomena. Instead, as the following formatting of our translation indicates, they pose a question and offer a complex clarification of its content.

> [*Question*]: Why do the Sun, the Moon, and the planets appear to move unsmoothly?
>
> [*Clarification*]: (i) After all, whether we hypothesize that their circuits are eccentric, or that the heavenly bodies go round along epicycles, the apparent unsmoothness of their motion will be saved, and (ii) [we] will have to go through *all* the modes according to which the phenomena[5] can be caused, so that (iii) our systematic treatment of the planets will resemble a theory of causes [set out] according to each possible mode [of explanation].

The question here is more general in nature than anything found in the preceding discussion, since it mentions the planets in toto, whereas F18EK had previously largely confined itself to issues involving the Sun, Moon, and Earth. But, more important, why is the question posed at all? If lines 32–39 are to be consistent with the basic thesis of F18EK, this question can only imply the need for a *physical* account of planetary motion. In that case, the purpose of the clarification that follows is to define the situation that will arise in the absence of such an account, *not* for astronomers but for the "we" of this passage. This collectivity must consist of Stoic philosophers who are committed to explaining planetary motion through physical theory. At least, if Posidonius is the author of lines 32–39, he could hardly be addressing astronomers as "we" after distinguishing them from philosophers in the preceding part of F18EK.

If our proposal here is correct, lines 32–39 express in broader terms than the rest of the passage why Heraclides' hypothesis (at 39–42) has to be rejected by a Stoic philosopher. That is, Stoic physical theory can demonstrate that the Earth is stationary while the Sun moves, whereas lines 32–39 reveal what the explanation of planetary motion would be like if there were no such physical theory to fall back on.

Thus part (i) mentions two hypotheses (those of eccentric and epicyclic motion) as familiar to "us" as ways of saving the phenomena. Whereas lines 30–32 had suggested that different astronomers could formulate different hypotheses, part (ii) now claims that if "we" admit these two hypotheses, "we" will be required to state every possible hypothesis that would explain unsmooth planetary

5. On this phrase see n. 32 below.

motion,[6] and part (iii) sums up by describing such an inventory as only "resembling" a theory of causes (an *aitiologia*). That is, it is not a real theory of causes, because it does not depend on physical theory, which, as we have seen, prescribes a *single* cause. Anyone saddled with this consequence might be able to reconcile different hypotheses *mathematically*, but would have to admit that different hypotheses had different, and irreconcilable, *physical* implications (see n. 30 below). There could be no better argument for requiring here, as elsewhere in F18EK, a single physical theory as the presupposition of astronomy.

Now a practicing astronomer of Posidonius' time did not, and would not, want to entertain a multiplicity of hypotheses, and it is implausible to suggest, as some scholars have, that lines 32–39 are actually licensing an astronomical program in which multiple hypotheses will be generated as a natural part of planetary theory, when that is pursued as an activity parallel, rather than strictly subordinate, to physical theory.[7] Instead these lines are best understood as a Stoic philosopher's sophisticated reaction to the problem raised by the historical fact that different

6. Presumably this would entail developing each hypothesis for each planetary body, if the hypotheses are to be quantified appropriately. This would amount to 21 hypotheses if to epicyclic and eccentric motion we add homocentric motion and attempt to explain the motion of each planet by each of these hypotheses. The writer may, of course, have had more than these three kinds of hypotheses in mind; after all, there were Babylonian arithmetical schemes for the planets as well as Greek versions of these schemes in play during the relevant time period; see Bowen and Goldstein (1991), and Jones (1999), especially at 1:5–34. Geminus for one uses a Babylonian scheme at *Isag.* ch. 18 to account for the Moon's unsmooth motion; see Bowen and Goldstein (1996) 167–171.

7. For this position see Kidd (1978a) and *Comm.* 132–136, and cf. Aujac (1975) 162 n. 6. Kidd sees the subordination of science to philosophy claimed by Posidonius as compatible with science's inherent employment of what he (Kidd) calls a "hypothetical method" (cf. n. 33 below). Kidd, however, fails to distinguish between the historical fact of different astronomers having *different* hypotheses regarding planetary motion, and the unique, and undesirable, situation envisaged at F18.32–39 EK, in which a *single* physical theorist will be obliged to adopt *multiple* hypotheses. The upshot of those lines is that Posidonius must be presented as deprecating hypotheses entirely rather than as wanting philosophy to "arbitrate" between them (Kidd *Comm.* 136). For further criticism of Kidd's conception of hypotheses in Posidonian texts see on *Caelestia* I.7 at nn. 4 and 11; also, on Posidonius and multiple explanations see on *Caelestia* I.4 at n. 25 and II.6 n. 21.

astronomers favored different hypotheses concerning planetary motion.[8] As such, lines 32–39 can be compared with an argument used by the Sceptic Aenesidemus (first century B.C.): that single causal explanations are unacceptable when, given the variety of evidence available, many modes of explanation are possible.[9] Aenesidemus sees such multiple explanations as unavoidable, and as undermining, by their very multiplicity, the whole program of causal explanation. The author of F18.32–39 EK, on the other hand, argues that multiple explanations will arise for anyone (philosophers as well as astronomers) when there is no criterion, in the form of an irrefutable physical theory, that can be used to decide which explanation is true.

F18.32–39 EK, then, does not in its present location in the text form a continuous part of the argument of this "fragment." It is at best tangential to it, both in being a query about how one should explain the apparent unsmooth motion of the planets in general, and in being a reflection on what follows for philosophers if they do not have a proper physical account rather than an inventory of astronomical practice. It then (lines 46–49) leads into a prescription directed to astronomers to temper their hypothesizing by starting from a physical account. Posidonius himself could certainly have employed such reasoning, both as a justification for physical theory, and as a further way of warning astronomers that,

8. Thus we reject the paraphrase of this particular text by Lloyd (1978) 213: "it is [the astronomer's] business to say in how many ways it is possible to save the phenomena." For Posidonius it is *nobody's* "business" to multiply hypotheses; instead, by being formulated with reference to physical theory, they lose any hypothetical status, and are necessarily not multiple. Lloyd (1978) 213–214 attributes an incoherent position to Posidonius in claiming that astronomy "presupposes" physics, while the astronomers' "business" is to state multiple hypotheses. He manages this by failing (at 214) to take full account of F18. 46–49. Here the astronomers are said *(a)* to take *"first principles,"* not "presuppositions," from the natural philosophers, and *(b)* to demonstrate "through" those principles only two types of motion (parallel and oblique) by the heavenly bodies. Lloyd quotes *(a)*, and ignores *(b)*, and thus seems to think that astronomers derive from physics only more remote principles (his "presuppositions")—simple, smooth and orderly motion—that are compatible with their positing multiple explanations. Instead, the format of their explanations is rigidly prescribed in *(b)*.

9. At Sext. Emp. *PH* 1.181. See Barnes (1983) 167–169 and (1990) 2665–2666 on this argument and its analogues in Quine's concept of data "underdetermining" theory, and cf. Introduction n. 25.

if they rely on hypotheses, then a single hypothesis may not really account for the phenomena. But there is no suggestion in lines 32–39 that Posidonius also wanted astronomers to entertain multiple hypotheses[10] among which philosophers would then arbitrate. On the contrary, he could only have held out the specter of multiple hypotheses as an additional way of demonstrating the need to constrain astronomical hypotheses by physical theory. That warning, however, is not directly conveyed by the language and reasoning used in lines 32–39.[11] The author of those lines is, as we have suggested, drawing the attention of fellow Stoics to a problem closely related both to the general thesis of F18EK, and to the specific case of Heraclides' treatment of "apparent unsmooth motion." He is, in other words, offering philosophical reflection that can be seen as enriching the simpler programmatic claims in the rest of F18EK.

F18.32–39 EK, then, clearly reflects some imperfect epitomizing and selection in the evolution of this whole text.[12] Yet these lines are still compatible with the mantra of F18EK: that astronomers "take first principles from natural philosophers." Astronomers who fail to do so risk having their hypotheses corrected by philosophers, an embarrassing result, yet nothing to compare with the

10. We thus question Kidd's attempt, however tentative, at *Comm.* 136 to put F18EK into some theoretical relationship with a well-known text at Simplicius *In de caelo* 32.29–32 that shows tolerance toward astronomers who develop different hypotheses to save the phenomena. Simplicius could have based his position on F18EK, which, of course, he quotes (see n. 13 below), but in doing so he would be misunderstanding Posidonius, as surely as Kidd does in supposing the Stoic philosopher to be defining science by its use of "hypothetical method" (see n. 7 above).

11. Kidd *Comm.* 132–133 paraphrases 32–39 by initially saying that "we" entertain different hypotheses for planetary motion, but then switches to talk of "*their* study of the planets" leading to a list of explanations. "They" are Kidd's "scientists" who work with "possible hypotheses"; but the text of F18EK clearly shows that it is the "we" of lines 32–39 who will have to cope with such hypotheses, and there is no reason to identify this group as astronomers (cf. n. 7 above).

12. The use of *οἷον* ("for example") at line 32 to introduce this passage in itself suggests that some preceding discussion has been lost. This would almost certainly have concerned the "apparent unsmooth motion" of the Sun mentioned in the comment on Heraclides at lines 39–42, and used as the basis of the reflections at lines 32–39.

nightmare faced by philosophers who are unable to explain the nature of the cosmos and are therefore engulfed by the multiple hypotheses indicated at F18.32–39 EK.

TRANSLATION

[13] Alexander [of Aphrodisias] assiduously quotes a specific text of Geminus, derived from [the latter's] epitome that expounds Posidonius' *Meteorologica*[14]—[a text] that takes its starting points from Aristotle.[15] It goes as follows.

It is for physical theory to inquire into the substance of the heavens and of the heavenly bodies, and into their power and quality; and into their coming into existence and destruction. Through these [investigations][16] it can certainly offer demonstrations concerning size, shape, and ordering. Astronomy, on the other hand, does not attempt to speak about anything of that sort. Instead, it demonstrates the order of the heavenly bodies after declaring that the heavens really

13. The passage, quoted by Simplic. *In phys.* 291.21–292.21 as part of his exegesis of *Phys.* 193b22–35, was taken from Alexander of Aphrodisias' lost commentary on Aristotle's *Physics.* Geminus' epitome provided these commentators with historical confirmation for Aristotle's distinction at *Phys.* 193b25–35 between astronomy and natural philosophy, which he introduced as part of a larger distinction between mathematics and natural philosophy in *Phys.* 2.2. See also nn. 20 and 21 below.

14. This follows Diels' proposal (apparatus criticus for Simplic. *In phys.* 291.22; noted, but not adopted, in EK) to supply *τῆς* after *ἐπιτομῆς*, so as to leave no doubt that this is Geminus' epitome of the Posidonian treatise. Literally, it is "the epitome, <the one> that is an exposition."

15. Since the Aristotelian text supplies only "starting-points" *(aphormai)*, or "points of departure," the Aristotelian origins of Posidonius' position are of limited significance; see Todd (1988) 307–308 on Sandbach (1985) 61.

16. With Bake (1810) 60 we read *νὴ Δία* <*διὰ*> *τούτων*, a supplement which Kidd *Comm.* 130 found only "tempting." But the supplement is palaeographically justifiable, and by emphasizing that it is "through," or on the basis of, physical theory that the topics of shape, size and order are pursued, it is consistent with line 17 below, where astronomy is said, by contrast, to make demonstrations "through" arithmetic and geometry.

are a cosmos,[17] and speaks about the shapes, sizes, and distances of the Earth, the Sun, and the Moon; and about the eclipses and conjunctions of heavenly bodies; and the quality and quantity of their movements.

14: It follows that since astronomy deals with the theory of quantity, duration, and type of shape, it is reasonable for it to need arithmetic and geometry for this.[18] And concerning these matters, which are the only ones about which it undertakes to supply an account, it has the authority to make inferences through arithmetic and geometry.

18: Now astronomers and natural philosophers[19] will in many cases propose to demonstrate essentially the same [thesis] (e.g., that the Sun is large; that the Earth is spherical), yet they will not follow the same procedures.[20] Whereas [natural philosophers] will make each of their demonstrations on the basis of substance, or power, or "that it is better that it be thus," or [the processes] of coming into existence and change, astronomers will do so on the basis of the [prop-

17. The "real" cosmos for the astronomers is the heavens, and Cleomedes frequently uses the Greek term *kosmos* in this sense. The natural philosopher, however, is more interested in the cosmos as the totality of matter; see, for example, *Caelestia* I.1.3–10.

18. Cf. the similar definition of mathematical astronomy at Ptol. *Alm.* 1.1, 5.25–6.4. Like Posidonius (lines 15–16 below), Ptolemy (6.19–21) also associates arithmetic and geometry with astronomy, but, unlike him, rates it above physical theory, on the grounds that it deals with unchanging matter, i.e., the Aristotelian aether (6.9–11; 6.23–7.3). Ptolemy limits physics to an analysis of the qualities of sublunary matter (5.19–6.14), an unstable object (6.11–15) that can support only "guesswork" *(eikasia)*, not generate knowledge. Given the diffusion of Posidonius' ideas in the first and second centuries (see I. G. Kidd [1978a] 11), Ptolemy may even be reacting to the program summarized in F18EK, while still maintaining the primacy of physical theory as the source of the cosmology presupposed by astronomers. On the latter see *Alm.* 1.7, and cf. Lloyd (1978) 216–217, and Wolff (1988) 499 n. 31.

19. Here and subsequently we interpret the definite article in the singular with "astronomer" and "natural philosopher" as *generic* in sense (that is, it refers to any member of the class, or to the class collectively) and have translated it consistently in the plural form. See further n. 26 below on the importance of this point.

20. On the common subject matter of astronomy and natural philosophy see *Phys.* 193b29–30. On the language of "procedures" *(ephodoi)* (here represented by *hodoi*, literally "routes") in the *Caelestia* see the Introduction n. 34.

erties] incidental to shapes or magnitudes,[21] or on the basis of the quantity of the movement, and the time interval appropriate to it.

25: And natural philosophers will in many cases[22] deal with the cause by focusing on the causative power,[23] whereas astronomers, when they make their demonstrations on the basis of extrinsic incidental [properties], have no adequate insight into the cause in, for example, claiming that the Earth, or the heavenly bodies, are spherical.[24] Sometimes they do not even aim to comprehend the cause, as when they discourse on an eclipse.[25]

30: On other occasions [astronomers][26] make determinations in accordance with a hypothesis[27] by setting out some modes [of explanation], which if they are the case, the phenomena will be saved.

21. *Phys.* 193b27 and 32–33 also refer to "incidental properties" *(sumbebēkota).* But since these are observable, the phrase here, and at line 27 below, anticipates the later reference (line 32 below) to "appearances" *(phainomena).* For *kata sumbebēkos* ("incidentally") glossed as "apparent" *(phainomenē)* see Theon *Expos.* 188.22.

22. Not, however, that of the void, which "does not act at all" (οὐδὲν ποιεῖ), i.e., cause any effects; see *Caelestia* I.1.99–100.

23. *poiētikē dunamis* (for the translation see I.3 n. 17). This phrase may suggest the general notion of the Stoic *logos* (Kidd *Comm.* 132), which is, of course, "active" *(poioun)*, but here it can be more specifically linked with earlier references (lines 6 and 21) to the power of *intracosmic* bodies to produce effects. In the *Caelestia* there are also references to the power of the cosmos to undergo change (I.8.92–95), of the Earth to nourish heavenly bodies (I.8.92–95), and of the Sun and Moon to produce terrestrial effects (II.1.357–404; II.3.61–67), while *Caelestia* I.2–4 emphasizes the Sun's causal role in producing variations in seasons and the lengths of daytimes and nighttimes.

24. Although Cleomedes grounds the sphericity of the Earth on observations (see I.5.104–113), but that of the cosmos (*Caelestia* I.5.126–138) on physical theory, the theory of centripetal motion (cf. I.6.41–43) still implies that the heaviest matter will necessarily arrange itself spherically at the center of the cosmos.

25. See *Caelestia* II.4.95–107 (with II.4 nn. 8 and 19) on the Posidonian physical theory underlying eclipses.

26. By interpreting the subject of the verb here, which is in the singular, as the class of astronomers, or "any astronomer" (see n. 19 above), we avoid having Posidonius claim that a given astronomer will adopt more than one hypothesis, as I. G. Kidd (see n. 7 above) would have him do.

27. At *Caelestia* II.1.310–311 and 332–333 similar language is used in connection with premises in a calculation of the size of the Sun, though there the

32: For example:[28] Why do the Sun, the Moon, and the planets appear to move unsmoothly?[29] After all, whether we hypothesize that their circuits are eccentric, or that the heavenly bodies go round along epicycles,[30] the apparent unsmoothness of their motion will be saved.[31] And [we] will have to go through *all* the modes according to which these phenomena[32] can be caused, so that our systematic treatment of the planets will resemble a theory of causes [set out] according to each possible mode [of explanation].[33]

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hypotheses are assumptions made within the larger argument rather than the kind of foundational hypothesis that concerns Posidonius here.

28. See the preface to this Appendix, and n. 12 above, on the relation of this section to the rest of the passage.

29. *anōmalōs:* on this terminology see Bowen (1999) 289–296.

30. Hipparchus seems to have evaluated both the epicyclic and eccentric theories purely as hypotheses (Theon *Expos.* 166.4–10), and was criticized (Theon *Expos.* 188.15–24), in terms consistent with Posid. F18EK, for "not being supplied 'for the road' *(ephōdiasthai)* from natural philosophy *(phusiologia).*" That is, he did not adopt a "procedure" *(ephodos)* grounded in physical theory.

31. The eccentric and epicyclic hypotheses are treated here as independent rather than equivalent, since Stoic philosophers (the "we" of this passage; cf. nn. 7 and 11 above) are concerned with their physical consequences. Also, no writer of the first centuries B.C. and A.D. mentions this equivalence, and those that do address the issue of the planetary motions choose one hypothesis or the other, and not both. (On the project of saving the phenomena of the planetary motions before Ptolemy, see Bowen [2001].) Ptolemy actually suggests the possible equivalence of the two hypotheses at *Alm.* 3.3 (cf. Toomer [1984] 144 n. 32), but does not discuss it until *Alm.* 12.1. On the strength of the latter text some modern scholars (e.g., Neugebauer [1955] and [1959]) suppose that the proof of this equivalence goes back to Apollonius of Perge (third century B.C.). But this overlooks the fact that the single demonstration Ptolemy gives in *Alm.* 12.1 of the planetary stationary points is his own, and that, according to Ptolemy, his predecessors made their cases for each hypothesis separately; see Bowen (2001).

32. The phenomena that are "saved" are identical, whichever hypothesis is adopted.

33. The phrase *κατὰ τὸν ἐνδεχόμενον τρόπον* (37–38) is best taken in this distributive sense. The translation "the possible method" at Lloyd (1978) 213 and Kidd *Comm.* 133 is vague and question-begging, and for Kidd "possible" is also a synonym for "hypothetical"; see n. 7 above.

39: That is why a certain Heraclides of Pontus actually came forward to say that the apparent unsmooth motion of the Sun can be saved[34] even if the Earth somehow moves, while the Sun somehow remains stationary.[35]

42: For in general astronomers do not have knowledge of what is by nature at rest and what sort of things are moved.[36] Instead, by introducing hypotheses of some things being stationary, others in motion, they investigate which hypotheses will follow from the phenomena in the heavens.

46:[37] But astronomers have to take as first principles from natural philosophers that the motions of the heavenly bodies are simple, smooth, and orderly, and through *these* [principles] they will demonstrate that the choral

34. In fact the Earth's motion and the Sun's immobility would not explain this apparent unsmooth motion (manifested, for example, in the inequality of the seasons) without some additional assumption, such as that the Earth moves on an eccentric circle.

35. On this text as evidence for Heraclides' cosmology see Gottschalk (1980) 62–69. A derogatory use of "a certain" (τις) and "somehow" (πως) would make Posidonius' whole report vague and dismissive, and therefore not worth pursuing in any detail in the present context. Heraclides is chosen probably because the *single* possible explanation that he gave from the multiplicity available was so unusual, and, for the Stoic Posidonius, so exceptionally counterintuitive.

36. The Stoic natural philosopher will know this, and what causes it, on the basis of the theory of the centripetal motion of the elements, whereby Earth, as the densest element, is stable at the center of the cosmos; see on *Caelestia* I.6 at n. 14, and also I.1 n. 57. Dercyllides (early first century A.D.; see on *Caelestia* at I.2 n. 9), cited at Theon *Expos.* 200.4–12, argues, much like Posidonius, that astronomers must adopt this theory from the natural philosophers. His position may reflect Posidonian ideas; see I. G. Kidd (1978a) 11 and *Comm.* 135.

37. Contrast the present paragraph, and lines 30–39 above, with Simplic. *In de caelo* 488.3–25. Here Simplicius similarly recognizes the existence of a true account of planetary motion that is based on physical theory, yet denies that this account, whatever form it may take, is the basis for definitively selecting the true astronomical account from a set of divergent theories. Instead, he sees astronomers as accounting for the phenomena of planetary motion on the basis of a few unexamined hypotheses about that motion. He does not claim that their divergent accounts must be reconciled with the single true physical (i.e., philosophical) account. His tolerance contrasts sharply with the position adopted in F18EK. Cf. also n. 10 above.

dance[38] of all [those bodies] is circular, with some revolving in parallel circles, others in oblique circles.

50: That, then, is how Geminus (or rather Posidonius [cited] in Geminus) transmits the distinction between natural philosophy and astronomy, and he takes his starting points from Aristotle.

38. *khoreia:* Kidd *Comm.* 133 compares Pl. *Tim.* 40c3. The point about a choral dance is that it involves intersecting circles.

GLOSSARY OF SELECTED TERMS

AETHER: *aithēr*
AIR: *aēr*
ANTIPODES: *antipodes*
APPEAR (BE SEEN): *phainesthai*, *phantazesthai*
APPEARANCE: *phantasia*
ARC: *periphereia*
ASSUME: *hupotithesthai*
ASSUMPTION: *hupothesis*
BODY: *sōma*
CAUSE (N.): *aitia*, *aition*
CENTER: *kentron*, *meson*
——, EXACT: *mesaitaton*
CIRCLE (N.): *kuklos*
——, ANTARCTIC: *antarktikos*
——, ARCTIC: *arktikos*
——, EQUINOCTIAL: *isēmerinos*
——, GREAT: *megistos*
——, HELIACAL: *hēliakos*
——, NORTHERN: *boreios*
——, SOUTHERN: *notios*
——, TROPICAL: *tropikos*
CIRCUIT (OF PLANETARY MOTION): *kuklos*
CIRCUMFERENCE: *periokhē*

CIRCUMHABITANTS: *perioikoi*
COEXTENSIVE WITH, BE: *sumparekteinesthai*
COINCIDENCE: *epharmogē*
CONCEIVE OF: *epinoein*
CONCEIVING, PROCESS OF: *epinoia*
CONJUNCTION: *sunodos*
CONTRAHABITANTS: *antoikoi*
COSMOS (= UNIVERSE): *kosmos* (see “heavens”)
——, WHOLE: *ta hola*
COURSE (OF PLANETARY MOTION): *poreia*
CRITERION: *kritērion*
CULMINATE: *mesouranein*
CURVATURE: *kurtōma*
DAY, DAYTIME: *hēmera*
DEMONSTRATE: *deiknunai*, *epideiknunai*
DEMONSTRATION: *apodeixis*
DETECT, DETERMINE (BY OBSERVATION OR CALCULATION): *heuriskein*
DIAMETER: *diametros*
DISAPPEAR: *aphanizesthai* (see “sight, out of”)
DISTANCE: *apostasis*, *diastēma*
DOCTRINE: *doxa*
EAST: *anatolē*
ECLIPSE: *ekleipsis*
ECLIPSED, BE: *ekleipein*, *ekleipsin poieisthai*
EFFECT (A MOTION): *poieisthai (kinēsin)*
ENCLOSE: *periekhein*, *perilambanein*
EQUINOX: *isēmeria*
ESTABLISH (A THESIS): *kataskeuazein*, *paristanai*
FIRE: *pur*
(1) FOOT WIDE: *podiaios*
HABITATION: *oikēsis*
HEAVENLY BODIES: *astra*
HEAVENS: *kosmos*, *ouranos*
HEIGHT: *hupsos*
HELIACAL: *hēliakos*
HOLDING-POWER: *hexis*
HOLD TOGETHER: *sunekhein*
HORIZON: *horizōn*

HYPOTHESIS: *hupothesis*
HYPOTHESIZE: *hupotithesthai*
ILLUMINATE: *lamprunein*, *phōtizein*
ILLUMINATION: *phōtismos*
IMAGINE: *epinoein*
INCORPOREAL: *asōmatos*
INDEFINITELY: *eis apeiron*
INTERVAL (OF A NIGHTTIME AND A DAYTIME): *nukhthēmeron*
INTERVAL (OF SPACE OR TIME): *diastēma*
LATITUDE: *klima; para* (with the dative case)
LENGTHENING: *auxēsis*
LIGHT: *phōs*
LIMITED: *peperasmenos*
LINE, STRAIGHT: *eutheia (grammē)*
LINE OF SIGHT: *opsis*
LUMINANCE: *lampēdōn*
MERIDIAN: *mesēmbrinos (kuklos)*
MONTH: *mēn*
MOON: *selēnē*
MOTION: *kinēsis*
——, based on choice: *proairetikē kinēsis*
MOVE (INTRANS.): *kineisthai*, *pheresthai*
NATURE: *phusis*
NIGHT, NIGHTTIME: *nux*
NORTH: *borras*
NORTHERN: *boreios*
NOTION: *ennoia*
NOTION, FORM A: *ennoein*
OBLIQUE: *loxos*
OBSERVE: *theōrein*, *tērein*, *horān*
OCCUPY: *katekhein*, *katalambanein*
OPPOSITION, BE IN: *diametrein*
OPPOSITION, IN: *kata diametron*
PERCEPTION: *aisthēsis*
PERIOD: *periodos*
PHASE (OF MOON): *phasis*, *skhēma*
PHENOMENA, THE: *ta phainomena*
PLACE: *topos*

PLANE: *epipedon*
PLANETS: *planētai*, *planōmena*
POINT: *kentron sēmeion*
POINTER: *gnōmōn*
POLE: *polos*
POWER: *dunamis*
PROBLEM (RAISE A): *aporia*, *aporein*
PROCEDURE: *ephodos*
PROTRUSION: *exokhē*
PROVE: *elenkhein*
PROVIDE: *parekhesthai*
PROVIDENCE: *pronoia*
RAY: *aktis*
RECEIVE: *dekhesthai*
REFRACTED, BE: *kataklasthai*, *periklasthai*
REFRACTION: *anaklasis*
RISE: *anatellein*, *anerkhesthai*, *aniskhein*, *anapheresthai*
RISE (N.): *anatolē*
SEASON: *hōra*
SECTION (OF A CIRCLE): *tmēma*
SEE: *horān*
SEND OUT (LIGHT, SHADOW): *apopempein*
SENSE PRESENTATION: *phantasia*
SET: *kataduein*, *kataduesthai*, *duesthai*
SETTING: *dusis*
SHADOW: *skia*
SHORTENING: *meiōsis*
SIGHT: *opsis*
SIGHT, OUT OF: *aphanēs* (see "disappear")
SIGN (ZODIACAL): *zōidion*
SIGNIFICATION: *sēmainomenon*
SIZE: *megethos*
SOLSTICE: *tropē*
SOUTH: *mesēmbria*
SOUTHERN: *notios*
SPHERE: *sphaira*
SPHERICAL: *sphairikos*
STADE: *stadion*, *stadios*

STAR: *astēr*, *astron*
STARS: *astra*
——, ALWAYS VISIBLE: *aeiphanē*
——, FIXED: *aplanē*
——, OUT OF SIGHT: *aphanē*
SUBSIST: *huphistasthai*
SUBSISTING, STATE OF: *hupostasis*
SUBSTANCE: *ousia*
SUN: *hēlios*
SUNDIAL: *hōrologion*
SURFACE: *epiphaneia*
TROPIC: *tropikos*
——, SUMMER: *therinos*
——, WINTER: *kheimerinos*
UNLIMITED: *apeiros*
VERTEX: *koruphē*
VISIBLE, ALWAYS: *aeiphanēs*
VOID: *kenon*
VOLUME: *onkos*
WANE: *meiousthai*
WANING: *meiōsis*
WATER CLOCK: *hudrologion*
WAX: *auxesthai*
WAXING: *auxēsis*
WEST: *dusis*
YEAR: *eniautos*
ZENITH: *koruphē*
ZODIAC, ZODIACAL BAND: *zōidiakos*
ZONE: *zōnē*
——, CONTRATEMPERATE: *anteukratos*
——, FRIGID: *katepsugmenē*
——, TEMPERATE: *eukratos*
——, TORRID: *diakekaumenē*

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