# *Science before Socrates: Parmenides, Anaxagoras and the New Astronomy* by Daniel W. Graham

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The purpose of Daniel Graham's intriguing study is to challenge what he takes to be a longstanding orthodoxy. According to the presumed orthodoxy, Greek science, specifically astronomy, did not begin until nearly the mid-fourth century BC, when theorists like Eudoxus began to test their theories against available empirical observations. In particular, so goes the orthodoxy, the sixth- and fifth-century Presocratic philosophers were not scientists: they saw no need for a method by which to test their theories. Graham argues to the contrary that scientific astronomy, as contrasted with speculative accounts of the cosmos, begins well before the end of the Presocratic period. And the unlikely progenitor of Greek scientific practice turns out to be none other than Parmenides! Graham develops his thesis by way of conducting a meticulous survey of the evidence going back to Thales and the other early Ionians, and presenting an imaginative and fascinating reconstruction of the theoretical implications of what can be reliably established as evidence.

Central to Graham's account, developed in chapters 3 and 4 of the book, is the concept of 'heliophotism',[1] the idea that the Moon's light is not original but is reflected sunlight. This discovery, he claims, originates with Parmenides.[2]

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[1] The moniker is said to derive from Alexander Mourelatos. It is not always clear whether the term denotes the *fact* that the Moon's light is reflected sunlight or the *belief* in that fact.

[2] Diels and Kranz 1951, 28B14: 'A light by night, wandering around the Earth with borrowed light.' Heliophotism is also attributed in our sources to Thales, but Graham dismisses the attribution [51]. Knowledge of heliophotism, he argues, is necessary for understanding the nature of solar eclipses, which in turn is necessary for predicting one. But, argues Graham, Thales would not have had the resources to do what tradition attributes to him: the prediction of a solar eclipse [51–53].

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Parmenides, by this account, treats heliophotism as a hypothesis, confirmed by observation of the regular and periodic succession of the phases of the Moon. From heliophotism numerous implications can in turn be derived, implications that cannot have escaped an astute reasoner like Parmenides. For if the hypothesis is confirmed in this way, it will follow that

(1) the Moon is opaque,
(2) the Moon orbits below the Sun,
(3) the Moon is spherical,
(4) the Sun and Moon are permanent bodies,
(5) the heavenly bodies are massy,
(6) the paths of some heavenly bodies go under the Earth, and
(7) together with the assumption of ἀντίφραξις (*antiphraxis*)[3] —the interposition of a third body in alignment between two others—eclipses can be explained in terms of astronomical alignments.[4]

Thus, the discovery of heliophotism represents the turning point in the story of the advent of science. Indeed, as Graham looks back to the cosmological theories of Parmenides' predecessors [ch. 1–2], he does not find anything resembling science in those theories. There, the observable behavior of celestial bodies is characteristically explained in terms of the occasional activity of winds and exhalations, and so on, emanating from the Earth and not in terms of universal and constant cosmic principles. In those theories, astronomical phenomena are subsumed under meteorological phenomena; and Graham dubs this way of regarding them the 'Meteorological Model' [78–84]. Importantly, such explanations are not open to empirical confirmation.

The significance of Parmenides' discovery, so continues the account [ch. 5], was not lost on his immediate successors, Anaxagoras and Empedocles.[5] Both of them explicitly affirm heliophotism [Diels and Kranz 1951, 59B18, 31B47] and all seven of the implications stated earlier are, as it happens,

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[3] There is no direct evidence that Parmenides understood the nature of eclipses and, hence, no evidence that he would have been in a position to explain solar or lunar eclipses by way of ἀντίφραξις. Anaxagoras will be the first theorist to propose that explanation [see below].

[4] All these 'entailments' [119] of heliophotism are brilliantly worked out on pages 111–121.

[5] An argument for the chronological priority of Anaxagoras' writings over those of Empedocles is woven into Graham's account in chapter 5.

included in a testimony on Anaxagoras [Diels and Kranz 1951, 59A42, A123], though not there presented in any systematic order that would show their derivation from heliophotism.[6]

An interesting sidelight on Anaxagoras' scientific methodology is cast by his belief that the Earth is flat. He has empirical 'confirmation' of this belief:

> The Earth's horizon at the rising or setting of the Sun or Moon is flat, not convexly curved, as it would have to be if the Earth were spherical. On the other hand, the shadow cast on the Moon in a lunar eclipse *is* spherical. If the shadow seen on the Moon were cast by the Earth, it should be a flat line.

To account for the sphericity of the shadow, Anaxagoras posits the existence of asteroids, celestial bodies otherwise unseen. It is *their* shadow that is seen on the Moon. This line of reasoning shows that Anaxagoras has a grasp of ἀντίφραξις, the idea that the darkening of the Sun or Moon is caused by the interposition of a body that blocks the light from the sun.

Anaxagoras' account of heavenly bodies takes them to be stony bodies hurled away by the centrifugal force of the vortex that hurls them out from the Earth's surface and maintains them in place in their orbits.[7] This picture relies on a single universal principle of motion and not on the multifarious *ad hoc* explanations of celestial motions invoked in the Meteorological Model. Graham marks this turning point as the advent of the 'Lithic Model' [134–136].

The assumption of ἀντίφραξις, as we learn in chapter 5, helps explain the otherwise mysterious statement attributed to Anaxagoras that 'the Sun is larger than the Peloponnese' [Diels and Kranz 1951, 59A42, 59A1] and '[the Moon is] as large as the Peloponnese' [Plutarch, *De facie* 932a]. Why should the Peloponnese serve as the standard of comparative measurement here? Graham's conjecture is highly plausible.[8] We know from computer-assisted research that on 17 Feb 478 BC a solar eclipse occurred in which the entire

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[6] Graham [125] attributes this absence of systematic presentation to a tendency, common among doxographers, to report doctrinal data out of their original contexts; he is nevertheless confident that Anaxagoras would have understood their logical dependence on heliophotism.

[7] A meteorite is a rocky body that returns to Earth [ch. 5, see below].

[8] Graham acknowledges Panchenko's earlier proposal to similar effect [149n24].

Peloponnese was obscured [see diagram: 150–151]. It is likely, as Graham maintains, that the 22 year-old Anaxagoras, then living in Athens—which also lay in the path of the darkening—would have heard reports from travelers from the Peloponnese to the effect that the entire peninsula was engulfed in the darkening caused by the eclipse. Identifying (on the assumption of ἀντίφραξις) such darkening with the shadow cast by the Moon as it blocks the Sun's light, Anaxagoras could then have concluded that the Moon's size is roughly equal to the size of its shadow, which included roughly the Peloponnese, and that the Sun's size exceeded that of the Moon—because the eclipse was annular, not total—and hence also of its shadow.

Another instance of Anaxagoras' deployment of a scientific methodology is associated with what ancient sources describe as his 'prediction' of the fall of a meteorite at Aegospotami in 467/6. Following Plutarch [Diels and Kranz 1951, 59A12], Graham takes this as a description not of an actual prediction but of the theory that heavenly bodies are stones or stone-like. The fall of the (stone-like) meteorite at Aegospotami would then have confirmed his theory over against earlier views that heavenly bodies are light and held aloft by winds and the like. In sum, the grasp of ἀντίφραξις and its role in solar eclipses, proof that the Moon is a massy, possibly stone-like body, suggests that all heavenly bodies are similarly stone-like. That theory received empirical confirmation at Aegospotami in 467/6.[9]

Parmenides and Anaxagoras thus turn out to be the protagonists of this story. In chapter 6, Graham sketches what he takes to be the reception of their 'scientific turn' by subsequent cosmological theorists. Here he briefly surveys the cosmological theories of Empedocles [see 284n5, above], Diogenes of Apollonia, Philolaus, and Democritus. Empedocles follows Anaxagoras in accepting heliophotism and in explaining solar eclipses in terms of ἀντίφραξις (though differing with him on other matters). Diogenes holds that there are asteroids that can fall out of orbits, and that heavenly bodies are (pumice) stones, thus accepting the 'Lithic Model' (though he apparently rejects helio-

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[9] Graham also discusses Anaxagoras' 'theories' about comets [165–170] and the Nile floods [170–174] but these theories are not ones for which he would have had empirical confirmation and so are not included for discussion here.

photism).[10] Philolaus subscribes to both heliophotism and ἀντίφραξις, though his account of the structure of the cosmos is strikingly different from that of Anaxagoras. Finally, Democritus accepts the Lithic Model as a basis for cosmology and also appears to accept heliophotism. His views on eclipses are difficult to determine but there is some reason to think that he accepted ἀντίφραξις as well.

Chapter 6 continues with a comparison of sixth-century cosmologies (under the Meteorological Model) and those of the fifth century (under the Lithic Model) [201–202], and a review of the doxographic tradition on the subjects of the Moon's light and the nature of solar and lunar eclipses. A critical revision of the tradition leads to the result that heliophotism does not appear until Parmenides but consistently thereafter; and that ἀντίφραξις, necessary for correct theories of eclipses, begins to appear with Anaxagoras and consistently thereafter.[11] While Plato is silent on the subjects of the source of the Moon's light and the nature of eclipses, Aristotle's grasp of ἀντίφραξις is in clear evidence in his famous example of syllogistic causal explanation in the *Posterior Analytics*,[12] and his explanation of the occultation of Mars by the Moon at the half Moon presupposes knowledge of heliophotism.[13] By the first century AD, ἀντίφραξις as the correct explanation of both lunar and solar eclipses is a settled science, presented uncontroversially in teaching manuals of the time [See, e.g., Geminus, *Intro. ast.*].

The final chapter 7 summarizes the argument made in the preceding chapters[14] and continues with a meditation on the significance of Anaxagoras for

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[10] Diogenes' assertion (as reported) that the Moon is like 'an ignited pumice stone' [cited on 191] appears inconsistent with heliophotism, though Graham does his best to avoid this implication [192].

[11] The exception is Berosus, a Babylonian priest who became Hellenized but retained the grip of Babylonian astronomy.

[12] *Aristotle, An. post. 2.*980a15–18: 'What is an eclipse? Privation of light from the Moon by the Earth's screening [ἀντίφραξις]...'.

[13] Aristotle, *De caelo* 292a3–6: 'For we have seen the Moon, half Full, pass beneath the planet Mars, which vanished on its shadow side and came forth by the bright and shining part.'

[14] Brief discussion is given in this summary of the claim that Meton and Euctemon deserve to be ranked as fifth-century astronomers. Graham dismisses the claim, arguing that their calculations are based on materials derived from Babylonian sources [236].

the history of astronomy, including a defense of Anaxagoras as a scientist against some anticipated objections. The book concludes with two appendices, the first presenting a survey of the most important historiographical literature on Greek science, with attention to the place that the various authors assign to Anaxagoras, and the second defending the author's realistic or objectivist account of science, which underlies the book's historiography, against various antirealist accounts.

Graham describes his account as a 'reasoned reconstruction' [see, e.g., 228]. As such, the account is both innovative and plausible. Whether it is successful in achieving its aim of revising the calendar of the birth of Greek science is another matter, however. For even if it is plausible to suppose that Parmenides and Anaxagoras might have arrived at their views by relying on empirical confirmation in something like the way Graham's account proposes, that is no proof that they actually did so. But even if we could know that they did in fact rely on such confirmation, that would still not suffice to establish them as the first scientists of Greek antiquity. To practise science is to commit oneself to a particular method of inquiry—to propose and assess theories only in so far as these are open to empirical confirmation. Even if Anaxagoras' theory about the stone-like nature of heavenly bodies did (fortuitously) receive confirmation in the descent of the Aegospotami meteorite, it does not follow that Anaxagoras proposed the 'lithic' theory as a hypothesis awaiting empirical confirmation. To find evidence of a self-conscious commitment to such a method, we must go to the fourth century.

This is not to disparage the case that Graham makes for Parmenides and Anaxagoras or to minimize their roles. It is simply to say that the transition in Greek thought from 'unfounded speculation' [10] to science properly so called is not a sudden moment but a process of historical development in which thinkers like Parmenides[15] and Anaxagoras played a much more important role than has hitherto been appreciated. If Graham had employed his well-crafted argument to make a case for elevating the importance of these two thinkers for their contributions to this transitional process, rather than introducing them as the first Greek practitioners of scientific astronomy, his project, though more modest, would have been stronger.

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[15] The irony involved in naming Parmenides (the archenemy of sense experience as a basis of knowledge) as the pioneer of empirical science is not lost on Graham [90–91].

## BIBLIOGRAPHY

Diels, H. and Kranz, W. 1951. edd. *Die Fragmente der Vorsokratiker*. 6th edn. Berlin.