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Something New Under the Sun in Anaximenes' Astronomy?

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Abstract: Anaximenes famously taught that the sun and other 'stars' do not move under the flat earth but around it and explained the night thereby. What he had in mind remains conjectural; the testifying fragments are ambiguous and apparently contradictory. The past 200-odd years have seen a plethora of dissenting interpretations. The bulk of these are here categorised into three groups: that the sun circles at a fixed height above sea level; that it follows the familiar inclined path by day and clings to the northern horizon by night; and that it revolves in a circular orbit inclined relative to the earth. The first two scenarios are repudiated, while the third is fortified with several suggestions. It is argued that Anaximenes' terms for 'above', 'below' and 'around' did not differentiate the altitudes of celestial bodies relative to the horizon, but the sizes of their orbits – as indicated by their projections on the earth's plane. The point would have been that bodies in space are far enough from the earth to stay away from anyone's zenith or nadir – perhaps with exceptions, following pseudo-Plutarch. This approach reconciles the variant readings in the fragments and obviates the need for emendations. The sun would still move through the north at night, but in an arc below the horizon – not horizontally over the Ocean or behind mountains, as some had it. Thus, Anaximenes would have enhanced Anaximander's discovery that space facilitates inclined circular orbits by surrounding the earth on all sides. Awareness of the far-northern midnight twilight and the *aurora borealis* may have fed into all of these worldviews, the former legitimately and the latter fallaciously.

Keywords: Pre-Socratic; philosophy; Anaximenes; sun; cosmology; Rhipeans

1 Introduction

Where does the sun go at night? How does it travel from its setting place on the western horizon to its rising place in the east without being visible to us? The philosophers endeavoured to move away from mythological answers to this age-old

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question by using rational arguments, but the road to the standard Ptolemaic theory of circular motions around a spherical earth was a long and convoluted one, still not fully understood today. This article focusses on the theory of the diurnal movement of the sun and other celestial bodies as formulated by Anaximenes of Miletus (*c*586-*c*526 BC), at a time when scientific and mythical thought could still cross-fertilise. The *doxa* in question is fraught with interpretive challenges, but it will be shown that an elegant solution to these is possible. The key elements were found as early as 1858–1887, but forgotten more than a century ago. A partial reinvention of the wheel in modern times made no waves.

At the outset, it will be helpful to stave off a common lay confusion. The sun's daytime path – like its invisible nighttime complement below the horizon – is not the same as the ecliptic. The former is a function of the earth's rotation around its axis, the latter of the earth's orbit around the sun. As seen from the earth, the ecliptic is the apparent path that the sun traces out in the course of the year against the starry background. As the sun follows its day arc, the ecliptic moves along with it at varying angles to that arc and the horizon, but it does so invisibly as the stars are outshone by the sun. At night, this wobbling of the ecliptic can be visualised by keeping track of a curve from east to west that approximately joins any visible planets, the moon and the zodiac as they move. Throughout this process, the angle between the ecliptic and the stationary local equator remains fixed at 23.5.[1]

2 The Sources

For Anaximenes, Diogenes Laertius stated succinctly:

> The stars move not under the earth, but around the earth.[2]

An alternative manuscript reading was 'above' (ὑπὲρ) for 'under' (ὑπὸ): 'The stars move not above the earth, but around the earth.'[3]

Almost identical is the information that Eusebius and Stobaeus extracted from the doxology of a pseudo-Plutarch whom modern scholars identify as Aetius (1st century AD):

1 Compare Couprie (2018, 24–9); (2003, 218–21).

2 Diogenes Laertius, *Lives and Opinions of Those Renowned in Philosophy*: *Anaximenes* (2.2), 3, ed. Dorandi (2013, 151). All translations are mine, except where indicated otherwise.

3 As above, MS. P[2], written by a corrector of MS. *Parisinus Graecus* 1759 (Paris: Bibliothèque Nationale de France), ed. Dorandi (2013, 151 n.). Menagius (1692, 71) already rejected this reading, but it was still followed in Boyer d'Argens (1771, 216 n.*) (not in the French editions).

> Anaximenes: the stars revolve not under the earth but around it.[4]

> That the stars revolve not under the earth but around it.[5]

Hippolytus adds a sartorial simile and a solar application to explain the night: "that the stars do not move below the earth, as others suppose, but around the earth, just as a felt cap turns around our head. And that the sun is concealed not by coming to be under the earth, but by being hidden under the earth's higher parts and through the distance between it and us having become greater."[6] In a section on mountains in the north, Aristotle cited a similar persuasion of many 'ancient meteorologists' (ἀρχαίων μετεωρολόγων) that "the sun goes not below the earth but around the earth and this region, and that it disappears and causes night because the earth is elevated towards the north".[7] He did not name these 'meteorologists', but will have called them that because he allocated "Earth's various parts and forms" (γῆς ὅσα μέρη καὶ εἴδη) to that discipline.[8]

A final source is Aetius as transmitted by the extant pseudo-Plutarch (early 2nd century AD?). On the surface, it contradicts the others: the stars "revolve under the earth and around it" (ὑπὸ τὴν γῆν καὶ περὶ αὐτὴν στρέφεσθαι).[9] Diels emended this to: "revolve not under the earth, but around it" (οὐχ ὑπὸ τὴν γῆν, περὶ αὐτὴν δὲ στρέφεσθαι).[10] Although this was widely adopted,[11] Couprie convincingly turned it down.[12] Mansfeld and Runia stuck with Diels, but on the questionable basis that the manuscript with pseudo-Plutarch postdates Eusebius and Stobaeus.[13] A pseudo-Galen of the 3rd to 5th century AD supports Couprie insofar as he also gives two

4 Aetius, *On the Physical Opinions Favoured among Philosophers*, 2.16.5, in Eusebius, *Preparation of the Gospel*, 15.47.3, ed. Mras (1983, 414).

5 Aetius, *On the Physical Opinions*, 2.16.5, in Stobaeus, *Anthology*, 1.24.1k, ed. Wachsmvth (1884, 203); cf. Wöhrle (2012, 328–9).

6 Hippolytus, *Philosophical Teachings or Refutation of All Heresies*, 1.7.6, eds. Laks and Most (2016a, 342–3). Litwa (2016, 35) translated τῶν τῆς γῆς ὑψηλοτέρων μερῶν as "the parts higher than the earth" rather than 'the earth's higher parts'. This strangely presupposes that they are not themselves earth. If the 'earth' is the land at sea level, a wrong assumption is invited about their nature, more on which below.

7 Aristotle, *Meteorology*, 2.1, 354a30–3, trs. Laks and Most (2016a, 350–1), but with πρὸς rendered as 'towards' rather than 'in'.

8 Ibid., 1.1, 338b25, ed. Lee (1952, 4).

9 Aetius, *On the Physical Opinions*, 2.16.5, eds. Mansfeld and Runia (2009, 487, 493) (cf. (2020b), 2098), tr. Couprie (2018, 114). Cornarius (1552, 255 and reproduced in Budæus 1557, 539) curiously translated *ad terram & circũ terram* ('towards/near the earth & around the earth').

10 Diels (1879, 346, cf. 136). The received wording, still followed in Kaltwasser (1797, 56–7), was first questioned in Zeller (1876, 228 n.) (English: 1881a, 276 n.); cf. 1919, 328 n.

11 e.g., Wöhrle (2012, 268); (1993, 44–5); Mau (1971, 88); Guthrie (1962, 137); Zeller (1856, 326–8).

12 Couprie (2018, 114–19).

13 Mansfeld and Runia (2020a, 943–5); (2020b, 2098); (2009, 488–94).

positives, but he substitutes ἐπὶ for ὑπὸ: 'above the earth and around it'.[14] Publishers printed this alongside a Latin rendition, which instead changed περὶ to *supra*: 'below the earth, as above it' (*sub terra, quo supra*). This composition, in both languages, is long since discredited, however.[15] A 9th-century Arabic translation resembles the Latin variant, but with the order reversed: "oberhalb und unterhalb der Erde".[16] In all this, the *lectiones difficiliores* are the two Greek ones before Diels' intervention.

There is common ground on various points: that Anaximenes' system was geocentric; that his earth had a flat surface, probably circular in outline; that it floated on air like a leaf in the wind; and that his heaven was spherical or at least hemispherical.[17] It is also agreed that the 'stars' in these passages include the sun, moon and other traditional planets, in their diurnal motion. Respecting the sun's path, ὑπὸ ('under') and περὶ ('around') must be competing descriptions of the nighttime segment. Opinions diverge on other matters. Was Anaximenes among Aristotle's 'ancient meteorologists'? How exactly did he envisage the movement of the sun and stars, using the hat metaphor? And is pseudo-Plutarch's version incompatible with the other sources? In the following examination, the various viewpoints are grouped into three categories.

3 Hypothesis 1: A Horizontal Circuit above Sea Level

The most eccentric take is that independently pioneered by West and Panchenko, then elaborated by Kočandrle.[18] The earth's surface as the lower boundary of space was a shared trait of the Ionian philosophers, says Kočandrle. Because of the sun's continuous presence above the earth, the subterranean movement in pseudo-Plutarch's passage looks inauthentic to him and Panchenko. According to them, Anaximenes placed the astronomical bodies in orbits around the north pole in a horizontal plane above the earth. Making much of the rôle of distance in Hippolytus' quote, they suggested that the Milesian explained their risings and settings as optical illusions caused by remoteness. The main reason that the sun's light is only seen by day would be Greece's position well south of the pole. Night resulted from the light

14 pseudo-Galen, *Philosophical History*, 13, ed. Kühn (1830, 273) = Charterivs (1638, 36).

15 Mansfeld and Runia (1997, 13, 21–4).

16 Qusṭā ibn Lūqā al-Ba'labakkī (AD *c*820–912), *Kitāb Flūṭarḫus fī l-Ārā' al-Ṭabī'iyya Allatī Taqūlu bihā al-Ḥukamā'* (*Plutarch's Book on the Physical Views Held by the Sages*), 152.16, tr. Daiber (1980, 152–3, cf. 395–6); Wöhrle (2012, 394–5).

17 Couprie refuted the hemispherical alternative: (2018, 102, 105–6, 125, 127–8); (2015, 7–9, 23–4, 30).

18 West (1971, 103); Panchenko (1999, 36); (2015); Kočandrle (2019, 101, 106–11); (2021, 254–8).

being limited to a finite 'bubble' and reaching not far enough to the south during the sun's northern leg. A secondary factor would be a shielding mountain at the centre, with likely roots in myth. This satisfied the textual requirement that the earth be 'high' towards the north. A wider orbit in winter than in summer explained the seasonal difference in daylight hours. And a close parallel was found in the Chinese *gǎi tiān* cosmology.

3.1 Objections

One would expect the doxographers to have been more direct about perspective-based transformations, contracting or expanding orbits, and perhaps Greece's position south of the centre if those are what Anaximenes had envisioned. Of course, any object moving away generally seems to shrink, but why should the sun, moon and stars only rapidly do so at the horizon, assuming constant velocity? Indeed, they are often thought to look somewhat larger when they are on the horizon. This is the so-called 'celestial illusion', with the 'sun illusion' and 'moon illusion' as subtypes. Aristotle, Posidonius (*c*135-*c*51 BC), and others invoked atmospheric refraction to account for it,[19] while Cleomedes (1st century BC to 2nd century AD) advocated a combination of that and a psychological effect now known as Emmert's law – that an object's perceived linear size increases with its perceived distance.[20] The contemporary view is that, when the sun nears the horizon, the atmosphere only distorts it into an oval form and reduces its luminance. The enlargement happens almost exclusively in the perception of the beholder, as Ptolemy wrote in *Optics*,[21] though the mechanism remains poorly understood.[22] If Anaximenes were bright enough to reassess sunrise and sunset as illusions caused by horizontal approaching and receding, he could scarcely have been in the dark about the illusion of expansion, but how could both types apply? Another shortcoming is practically insuperable. Sunrise

19 Aristotle, *Meteorology*, 3.4, 373b13; Posidonius, in Strabo, *Geography*, 3.1.5; Disarius, in Macrobius, *Saturnalian Dinner Parties*, 7.14.2; Ptolemy, *Mathematical Syntaxis*, 1.3, tr. Toomer (1984, 39); old scholiast on Aratus, *Phenomena*, 847–50, ed. Martin (1974, 419–20).

20 Cleomedes, *On the Orbital Theory of Celestial Bodies*, 2.1.1-56, ed. Todd (1990, 44–6), trs. Bowen and Todd (2004, 99–102). Note that Hyginus, *On Astronomy*, 4.14, ed. Viré (1992, 154), does not belong in this context, but makes the point that the moon in any position not only *looks* smaller than the sun, but also *is* smaller in absolute size, despite being so much nearer the earth. He was followed in Isidore, *On the Nature of Things*, 16.3; *Etymologies*, 3.47; compare Cassiodorus, *Institutions of Divine and Secular Learning*, 2.7.2.

21 Ptolemy, *Optics*, 3.59–60, tr. Smith (1996, 151). However, for Ptolemy the illusion was the smaller image higher up, not the larger one at the horizon.

22 Gregory (2008, 407, 416–7); Lehn and van der Werf (2005); Ross and Plug (2002); Ross (2000); Toomer (1984, 39 n.24); Meinel and Meinel (1983, 14); Ross and Ross (1976).

and sunset involve the horizon visually cutting off a diminishing or increasing portion of the sun disc. If Panchenko and Kočandrle were right, the sun should instead be seen to become larger or smaller while retaining its full circular shape above the horizon.

On the lexical plane, as Kočandrle admitted, it is surprising that Anaximenes would have used the word περὶ ('around') instead of ὑπὲρ ('above') if his message was that the sun is above the earth even at night.[23] Furthermore, keeping the celestial bodies above the horizon at all times would mean an unlikely regression from Anaximander's revolutionary insight that space extends below the earth as well as above it.[24] This drawback, too, was conceded by Kočandrle and Panchenko.[25] And lastly, the existence of a potential Chinese analogue carries little weight. Pending proof of a direct, historical connection, its use risks a circular argument.

4 Hypothesis 2: A Kinked Circuit above Sea Level

The second, most popular interpretation restricts the motion of the heavenly bodies to the space above sea level without recourse to illusions. Instead, it denies them a circular orbit. The force of the air that supports the earth, the resistance of the surrounding ocean, the lack of space between the earth and the perimeter of the cosmos, or some other cause bends their paths at their places of setting, so that they laterally move 'around' the earth, along the northern horizon, until they rise again.[26]

23 Kočandrle (2019, 106); Couprie (2018, 118–20, 122–3); cf. Zeller (1876, 228 n.) (English: 1881a, 276 n.) = (1919, 327 n.).

24 On Anaximander's intellectual breakthrough, see Couprie (2018, 56); (2011, 87–120); (2003, 201–11); Wöhrle (1993, 23–4); Guthrie (1962, 99–100).

25 Kočandrle (2021, 255, 262–4); (2019, 105, 112, 116); Panchenko (2015, 412–13, 423–4). See the appendix for an obscure church father who blamed night on the sun's distancing, but with faulty logic and no bearing on Anaximenes.

26 Regnault (1734, 73); Boyer d'Argens (1738, 446) = (1765, 13); (1740, 134–5); de Jaucourt (1765, 878); Schaubach (1802, 135–6, pl. 4 figure 4); Öttinger (1850, 67–8); Gruppe (1851, 46–7); Zeller (1856, 183); (1869, 211) and still allowing in (1876, 228 n.) (English: 1881a, 276 n.) = (1919, 327–8 n.4); Gomperz (1896, 48–9) (English: 1901, 58); Heath (1913, 41–3); Kiessling (1914, 847–52, 871); Rey (1933, 409); Cherniss (1935, 343); Thomson (1948, 96); Dreyer (1953, 16); Guthrie (1962, 138); Bolton (1962, 42, 188 n.6); Kirk (1962, 290); Kirk and Raven (1963, 156–7); Fehling (1985, 208, 231); (1994, 139–47); Wöhrle (1993, 23–5, 74); Couprie (2011, 163–4); Graham (2013, 64, 65 figure 2.2); (2018, 167); Schleicher (2014, 13–14, 182, 192, 220, 237, 249, 265 (where he accidentally says "Anaximander"), 379); Geus (2018, 404); Podossinov (2019, 196–7); Mansfeld and Runia (2020a, 943); Gagné (2021, 49); Roller (2022, 163); dismissed by Röth (1858, 257–8, notes: 48 n.298); Teichmüller (1874, 92–8, 100, 102–4); Sartorius (1883, 33); Goebel (1910, 36); Robinson (1968, 45); Bicknell (1969, 78); Panchenko (2015, 414, 420); Couprie (2015, 21); (2018, 103–4, 113, 119–26, 128).

The parts of the flat earth that conceal the sun's light by being 'higher' (ὑψηλοτέρων) would be mountains, as was already noted in the margin of a 14th-century manuscript of Hippolytus.[27] Classicists were aware of the passage from Hippolytus by 1692,[28] but the mountains only definitively entered Anaximenean studies with Regnault in 1734.[29] A cosmology with such a screen of mountains had undoubtedly existed at some time. Though seldom cited on this score, Hyginus (*c*64 BC – AD 17) in no unmistakable terms informed that 'some' (*nonnulli*) had said that the obstruction of the light 'comes about because of the sun's course and, as it arrives at that place where it is said to set, the sun's light is averted from us by the vastness of the mountains there, and so night is seen.'[30] One only needs to think of Cosmas Indicopleustes (fl. AD *c*550) as a latter-day example.[31]

Most supporters of this line of argument, too, rejected pseudo-Plutarch's unaltered wording. One early exception was Öttinger.[32] Knowing only pseudo-Galen's version 'above the earth and around it', he forged a link with the two components of the bent orbit: above the horizon by day and around it by night. The philology, as seen, negates this effort.

Writing in 1869, Eduard Gottlob Zeller (1814–1908) was the first to identify Anaximenes as a referent in the pertinent passage from Aristotle. Gustav Teichmüller (1832–1888) disagreed with him, arguing that Anaximenes propounded a very different theory, discussed below, and that Aristotle was alluding to mythographers who pictured the god Helios travelling back around the earth's north side on the river Ocean, asleep maybe in a conveyance like a goblet or bed. That myth had been attested as far back as the late 7th century BC, in the poetry of Pisander, Mimnermus, Stesichorus and others.[33] Zeller countered that Aristotle consistently called the

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27 "ὑπὸ τῶν ὑψηλοτάτων ὀρῶν", MS. *Laurentianus* IX 32, *fols*. 307–318, in Marcovich (1986, 67 n.).

28 Menagius (1692, 71).

29 Schmidt (1689, 29–30) privately obtained the passage from Menagius, but apparently only the first part, for in his essay on Anaximenes he gleaned only that the sun stays above the horizon.

30 "solis cursu evenire et, cum pervenerit ad eum locum ubi occidere dicatur, ibi montium magnitudine a nobis lumen averti solis, et ita noctem videri." Hyginus, *On Astronomy*, 4.9, ed. Viré (1992, 136).

31 Cosmas Indicopleustes, *Christian Topography*, 2.34; 4.11–16; 6.1, ed. Wolska-Conus (1968, 338–41, 550–9); (1973, 12–13).

32 Öttinger (1850, 67).

33 Athenaeus (fl. AD 200), *Learned Diners*, 11 (469d-70c, 781d), citing Pisander (*Herakleia*, 2), Mimnermus (*Nanno*), Stesichorus (*Geryoneis*), Pherecydes (*History*, 3), Aeschylus (*Heliades*), Panyassis (*Herakleia*) and Antimachus, tr. Olson (2009, 240–1, 276–81). The sleeping is only mentioned by Mimnermus and hints at darkening (Kiessling 1914, 854). Schaubach (1802, 105–8, 135) had reviewed this mythical motif and submitted that Thales integrated it into his theory, but not Anaximenes.

exponents of myth 'theologians', not 'meteorologists' – the word he used here.[34] Max Hermann Kiessling (1877–1946) sided with Zeller, but felt that Aristotle misrepresented Anaximenes, who would have imagined a *ring* of low mountains around the *whole* earth for the sun to hide behind. The northern part that Aristotle had in mind would have been the Rhipeans above all.[35] Aristotle situated these directly beneath the pole, though he doubted reports about their size.[36] It was not until 1948, it would seem, that someone explored a middle ground with Anaximenes using the mountains to rationalise the old myth of Helios on the Ocean and Aristotle referring to both.[37] Consensus was never reached; Couprie stands out by aligning with Teichmüller.[38]

4.1 Objections

A kinked course around an earth supported from below would again have undone the progress made by Anaximander in regards of an annular orbit centred in uniform space.[39] The justification that the heavenly bodies could not – on Anaximenes' logic – descend into the air or water below the horizon is sheer conjecture. It is not found *expressis verbis* in the sources. Concentrated matter may have held up the earth, but not extended beyond the earth's perimeter. Kiessling adduced Anaximenes' teaching that "the heavenly bodies are pushed off course by condensed and resistant air."[40] That, however, concerned the solstices; the sun's diurnal and annual motions should not be confounded and such air would 'push' along a north-south axis, not a top-bottom one.[41]

As well, the doxographers should have been more forthcoming about mountains of such import. Hippolytus did not explicitly identify the 'higher' parts as mountains. This seems credible, as Anaximenes could hardly have done so. When it came to the cause of the nightly extinction of sunlight, woolly thinking could have passed muster in mythical mindsets but would not go down well with those grounding themselves in careful observation. If the sun's luminosity was steady, not extinguished every night

34 Zeller (1876, 227 n.1) (English: 1881a, 275 n.2) = (1919, 327 n.4). Compare Aristotle, *Meteorology*, 2.1, 353a35-b1.
35 Kiessling (1914, 846–50, 852, 864, 866, 869–72, 875–6).
36 Aristotle, *Meteorology*, 1.13, 350b7–9. Compare Sidonius, *Poems*, 2.244.
37 Thomson (1948, 36, 96).
38 Couprie (2018, 8, 30, 119–23, 126–7); (2015, 23).
39 Öttinger (1850, 66–8); Kiessling (1914, 848); Guthrie (1962, 137–8); Couprie (2015, 21); (2018, 124).
40 Kiessling (1914, 849–50), citing Aetius, *On the Physical Opinions*, 2.23.1 – trs. Mansfeld and Runia (2009, 561); (2020b, 2101); cf. in Stobaeus, *Anthology*, 1.25.1d; Laks and Most (2016a, 352–3).
41 Compare Diogenes Laertius, *Lives*: *Epicurus* (10), 93.

as the god slept, what caused it to be cyclically shrouded from Greek eyes? If mountains, how could the sun be seen to rise or set at sea level and not some distance above it? How could the twilight touch a horizon of sea or plains? How could stars like Capella (α Aurigae) be noticed just above the northern horizon if mountains were supposed to be occluding the sun's transit there? And to avoid twilight persisting the whole night, such prominences would have to be so high that the earth might not pass for flat.

What is more, Hippolytus did not restrict the 'higher' parts to the north either.[42] The abrupt bends in the solar trajectory could not be limited to the north, because sunrise and sunset occur to the southeast and southwest of any observer between the autumn equinox and the vernal equinox.[43] It was to circumvent this that Kiessling resorted to mountains all around the earth for Anaximenes.[44] Certainly, such a ring was a common notion both in ancient Near Eastern worldviews of a mythical bent[45] and in pre-Socratic thought – as the boundaries of a concave or bowl-shaped earth.[46] In the footsteps of Zeller and Kirk,[47] Mansfeld and Runia contemplated the sun on "a plane parallel to the flat earth, dipping below the horizon but not going all the way below the earth."[48] Neither design offers a convincing way out for the observational concerns just raised, however. The mountains shade into the earth's edges. One way or another, the philosopher had to confront the patent reality that the sun's cover is the horizon or sloping earth itself, with a separation large enough to prevent a twilight from appearing all night as the sun migrates eastward. The bottomline is that Anaximenes defended a northern route for the sun's nocturnal return, but surely discarded the myth that it clings to the horizon in that pursuit.

Aristotle, for his part, used words so similar to Hippolytus' as to rule out that the two accounts be unrelated. Could Hippolytus – along with all other sources except pseudo-Plutarch – then have been drawing on Aristotle's statement in a false belief that it applied to Anaximenes?[49] Not quite, because the details about the hat and the

42 Couprie (2018, 120).

43 Panchenko (2015, 414, 420); Couprie (2018, 104–5, 113, 120); Kočandrle (2019, 108); (2021, 256). Schaubach (1802, 136, pl. 4 figure 4; cf. Heath (1913, 41)) did not see this and figured that, as far as the fixed stars are concerned, their routing along the northern horizon precluded their courses from running parallel to each other. Sartorius (1883, 33) found such a scheme too absurd for Anaximenes.

44 Kiessling (1914, 847, 850).

45 See, conveniently, van der Sluijs (2020, 9).

46 e.g., Archelaus, in Hippolytus, *Philosophical Teachings*, 1.9.4, trs. Laks and Most (2016b, 196–7); Epicurus, *On Nature*, 11, in *Herculaneum Papyri*, 1042.8 I-II + 154.22 III - 23 I; 1042.8 VI, tr. Vassallo (2021, 130–4).

47 Zeller (1876, 228 n.) (English: 1881a, 276 n.) = 1919, 327–8 n.4 ("oder nur wenig unter die Ebene des Horizonts"); Kirk (1962, 290) ("slightly below its rim, perhaps").

48 Mansfeld and Runia (2020a, 943).

49 So Couprie (2018, 119, 122, 126); (2015, 22–3); compare Fehling (1994, 145); (1985, 208, 225).

sun's increased distance at night are not in Aristotle. For all the world, it looks like Hippolytus and Aristotle independently relied on the same source.[50] Consequently, it stands to reason that the Stagirite considered Anaximenes to be exemplary of the ancient true scientists he dubbed 'meteorologists'. He appears to have used Anaximenes' theory as an expedient to buttress his cause of all rivers originating from mountains, the highest ones being in the north, but in doing so employed the phraseology of the earth there being 'high' (ὑψηλὴν) advisedly. Evidently, Anaximenes' light-blocking barrier had gone beyond mountains and Aristotle as well as Hippolytus appreciated that.

Kiessling's identification of the northern heights with the Rhipeans muddied the waters. This legendary massif was definitely associated with cold and darkness in the far north, even beyond the sun's solstitial rising and setting places,[51] but Kiessling's influence notwithstanding it turns out that not a single source unambiguously names it as causing night or solstice.[52] This is not to deny that some – as seen – assigned the particular function of masking the sun's light to unnamed mountains, but Anaximenes and Aristotle may have known nothing about that. As documented elsewhere, the *fons et origo* of that fancy could have lain in mariners' tales of arctic mirages filtering through in the Hellenistic period.[53]

5 Hypothesis 3: An Inclined Circuit above and below Sea Level

The two camps evaluated so far both apply the word περὶ ('around') as used in the fragments to a path, circular or kinked, that never reaches below the horizon or sea level. A third option is the familiar notion of circular orbits on tilted planes, above and below a flat earth. This view was put forward first by Eduard Maximilian Röth (1807–1858) in 1858, found favour with Teichmüller and some more 'old Germans', and was championed more recently by Robinson, Bicknell, McKirahan and Couprie, each in his own way.[54] It would have been in agreement with Anaximander's precedent.

50 Mansfeld and Runia (2020a, 941, 944).

51 Hippocrates, *On Air, Waters and Places*, 19.

52 *Contra*, e.g., Bilić (2021, 39–42, 44, 55, 57–8, 68, 85–6, 89); Podossinov (2019, 194, 196).

53 van der Sluijs (forthcoming).

54 Röth (1858, 257, cf. 153); Teichmüller (1874, 98–104); Zeller (1876, 227–8 n.1) (English: 1881a, 276 n.) = (1919, 327–8 n.4); Sartorius (1883, 34); Berger (1887, 53–4); (1894, 27–9); (1906, 32); Goebel (1910, 36–7); Boll, in Kopff (1914, 361 n.); Robinson (1968, 45); Bicknell (1969, 77–9); McKirahan (2010, 56–7); Couprie (2015); (2018, 99–129); dismissed by Bolton (1962, 188 n.6); Kirk and Raven (1963, 157); Kočandrle (2019, 106). Bilić (2021, 85, 89) remained neutral.

Teichmüller and Zeller – when he came round to this perspective in 1876 – still opined that Anaximenes, on top of the sun's greater nighttime distance, needed northern mountains lest some light remain visible in that direction. In 1887, Ernst Hugo Berger (1836–1904) simplified the theory by suggesting that an elevation towards the north that Aristotle mistook for mountains had been astronomical – not geological – for Anaximenes: the celestial pole appears closest to the earth in that quarter.[55] As seen from Miletus or Delphi, its altitude is 37°–38°. If it were overhead, the celestial bodies would move parallel to the surface. Some pre-Socratics taught that this had been the original condition on the flat earth. Following Berger unknowingly, and some others, Couprie argues that Anaximenes was among them and charged the term 'around' with this special significance: *in illo tempore* the heavenly bodies always circled the earth horizontally, without rising or setting, and now they continue this peripheral movement at an angle to the horizon.[56]

Röth regarded pseudo-Plutarch's text – then still unemended – as more authentic than the other witnesses. Unlike his peer Öttinger, he knew it as 'under the earth and around it', explaining that it at once covered the movement below the horizon and in a tilted orbit.[57] While most later scholars differed, Couprie independently deduced the same, with the added slant of the primordial state for the meaning of 'around'.

The solution of inclined orbits is here accepted. The following sections will refine it in several respects.

5.1 Tilted Earth or Sky?

On a flat earth, the inclination of the pole poses a dilemma: is it the pole or the earth that is inclined in absolute space (Figure 1)? What was Anaximenes' preference? Berger, Robinson and Bicknell opted for the tilted earth; Aristotle could then have grouped him with 'meteorologists' like the atomists Leucippus and Democritus, who reputedly held that the earth tilts down towards the south.[58] McKirahan asserted that Anaximenes had a horizontal earth with a tilted sky (Figure 2).[59] Assenting, Couprie

55 Berger (1887, 53–5); (1894, 29); (1906, 32); cf. Goebel (1910, 37); Zeller (1856, 328 n.). Burnet (1892, 81; 1920, 77) and Gilbert (1907, 680–1) conflated this with northern mountains.

56 Berger (1887, 55 n.); Goebel (1910, 36–7); Bicknell (1969, 78); Fehling (1985, 201–2); Couprie (2015, 21–5, 29); (2018, 24–8, 102, 109, 121, 126–8).

57 Röth (1858, 257, notes: 48 n.298).

58 Berger (1887, 54); (1906, 32); Robinson (1968, 45); Bicknell (1969, 78–9).

59 McKirahan (2010, 56–7).

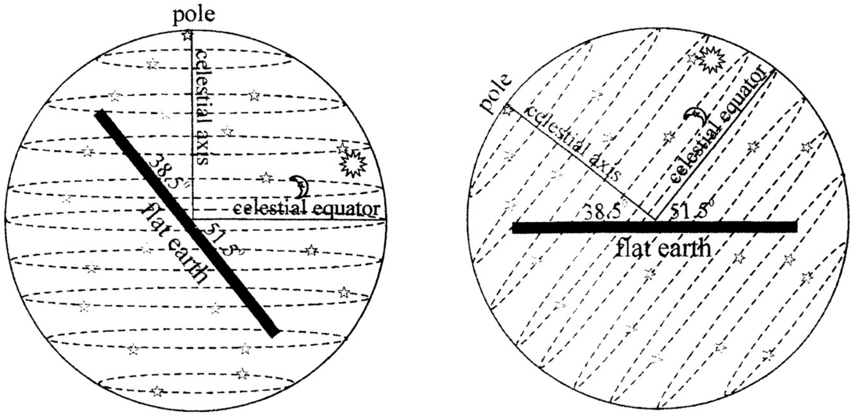

Figure 1: Two ways of visualising the inclination of the pole relative to a flat earth in space: by tilting the earth (left) or the sky (right). The inclination of 38.5° corresponds to the latitude of Delphi (Greece). Accordingly, Delphi is at the centre of the earth in the diagram. In the course of the year, the sun's orbit slides up and down along the axis while retaining the same radius. At the equinoxes, the sun moves on the celestial equator, in spring and summer north of it (shown here) and in autumn and winter south of it. Couprie (2018, 110 figure 7.6). © D. L. Couprie.

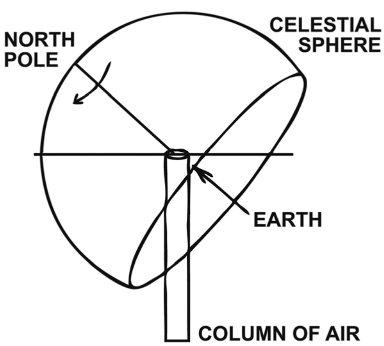

Figure 2: McKirahan's reconstruction of Anaximenes' cosmology. McKirahan (2010, 57).

subjoined that the reports on Leucippus and Democritus must have been garbled by ancient doxographers.[60]

60 Couprie (2015, 13–21); (2018, 28–31, 105–10, 119, 126). Couprie (2018, 20, 26, 42, 52, 121, 250) also counted Archelaus among the supporters of a tilted sky, but in combination with the above-mentioned peripheral ring of mountains. According to his fragment cited above, the concave earth was originally filled with a pool of water, while the sun circled around the horizon at a constant height, hidden from view by the raised rim; it was only when the sky acquired its tilt that the sun could illuminate the sky for part of the time and dry up the earth.

Kirk and Raven saw the attraction in the "tilted-earth hypothesis", but dismissed it anyway on two grounds: that "the earth would not thus float on air, but would slip downwards as leaves do" and that Aristotle conceived of the 'higher parts' as mountains.[61] Bolton, as an *advocatus diaboli*, would overcome the first objection with Anaximenes' earth being "a cross-section of a cylinder with the upper surface bevelled."[62] The base would have been horizontal and only the surface inclined, perhaps due to the south caving in. Short of approving that stance, it is actually easy to reconcile a tilted position with supposed aerial support by assuming different densities of air between north and south.[63] Nor do the sources state that the air was only supportive in the cosmos' vertical direction – and leaves float on air in any direction.[64] Indeed, Anaximenes also had the sun and moon ride the air like leaves.[65] The fact that we can see them face-on proves that not all flat objects in his cosmos shared the same orientation.

As for Aristotle, it was already proposed above that he knew Anaximenes' 'higher' parts to have been non-geographical. Bicknell gathered that Anaximenes and the two atomists "held that the world's greatest rivers flow down from the north of their tilted earth" due to the tilting rather than mountains.[66] Critics were troubled by the angle of 52°–53° required by the Ionian altitude of the pole, which would cause all of the earth's water to rapidly accumulate in the south,[67] and by the Nile flowing in the opposite direction to Europe's rivers.[68] Even if the Nile were pushed upward by pressure from its southern source, as Cosmas later averred,[69] it could never negotiate such steepness. These are not serious obstacles, however. They overlook the hydrological cycle, which Aristotle was at pains to figure out.[70] The southern heat would evaporate much of the water and feed it back into the loop. And it was only in *c*430 BC – long after Anaximenes – that Herodotus drew attention to the anomalies of the

61 Kirk and Raven (1963, 157); cf. Couprie (2015, 16); (2018, 28–31).

62 Bolton (1962, 188 n.6); cf. Panchenko (2015, 423–4).

63 Bicknell (1969, 79).

64 *Contra* Robinson (1968, 44).

65 Aetius, *On the Physical Opinions*, 2.22.1 (cf. 3.10.3; 3.15.8), trs. Laks and Most (2016a, 350–1); cf. Hippolytus, *Philosophical Teachings*, 1.7.4, trs. (2016a, 342–3); pseudo-Plutarch, *Miscellanies*, 3, trs. (2016a, 340–1); Aristotle, *On the Sky*, 2.13, 294b14–21; Plato, *Phaedo*, 99b. Compare Kirk and Raven (1963, 151, 153–5).

66 Bicknell (1969, 79).

67 Zeller (1856, 612 nn.1,5) = (1876, 802–3 nn.1,5 (English: 1881b, 251–2 nn.1,5)); Couprie (2015, 16–17, 20–1); (2018, 29–30, 109).

68 Couprie (2015, 21); (2018, 109).

69 Cosmas Indicopleustes, *Christian Topography*, 2.32, ed. Wolska-Conus (1968, 336–7).

70 Aristotle, *Meteorology*, 1.9–2.2, 346b16–356b3.

Nile and Egypt in general. In the process, he pondered the sun's intense drawing of water from the Nile in winter and from more northern rivers in summer.[71]

More to the point, the connection with rivers as well as mountains could be just Aristotle's spin on the subject to begin with, in a scramble to draw support even from the old ideology of a flat tilted earth. Going by the available fragments, the pre-Socratics only discussed the earth's dip in relation to the positions of the celestial bodies and the distribution of climate.[72] They may have correctly intuited some protogravitational theory by which the earth's orientation in space does not affect the surface water. In a universe where air can be distributed unevenly above and below the earth, it is not obvious that there should be a universal 'up' from which water flows 'down'. A person perpendicular to the surface of a flat tilted earth does not perceive the horizon as raised. Just so, water can be at rest on the tilted plane. That people do not "have the slightest awareness of living on an earth tilted that much"[73] is not more mysterious than that people on the bottom of the real terrestrial globe do not feel upside down. The answer is gravity.

The hypothesis of an earth inclined as a whole or only at its surface is, therefore, still on the table.

5.2 Relative Highness

Perhaps Anaximenes meant the 'high' parts of the earth not as geographic relief or absolute astronomical directions, but was merely using relative terminology. Relative to what, though? McKirahan could see the north of a level earth being called 'higher' than its south by virtue of the pole's inclination towards it.[74] A more intuitive comparison would be with the sun when that is hidden from view: at night the earth's surface is 'higher' than the sun, just as it is 'below' the sun during the daytime. Not catching this, Aristotle could have ascribed a tilted earth to Anaximenes to suit his theory of rivers.

Reading 'higher than the sun' instead of 'higher than other parts of the earth' or 'higher than us' satisfies the requirement that the high parts must include Greece in the winter season, when the night begins and ends with the sun south of the equator. Aristotle's specification that the elevation is 'towards the north' (πρὸς ἄρκτον – note the accusative case) does not have to mean north of Greece, but can indicate the direction for the earth as a whole. The emphasis is on *towards*; night occurs because the earth is not parallel with the sun's circuit but higher than the sun at its northern end.

71 Herodotus, *Histories*, 2.19–34.

72 Compare Couprie (2015, 17).

73 Couprie (2015, 16), translating Wöhrle (1993, 75).

74 McKirahan (2010, 56).

5.3 Proportionality of the Sun's Orbit and the Earth

Granted that Anaximenes' 'around the earth' described inclined circular orbits, it still requires elucidation why he placed that concept in opposition to 'below the earth', according to all witnesses except perhaps pseudo-Plutarch, and possibly even to 'above the earth'. It may be that the original dialectic has been misunderstood. The traditional understanding has been that Anaximenes' 'below' relates to the horizon, which coincides with the entire plane extending out from the flat earth's surface. Might it instead refer only to the space below the actual earth?

Suppose that the philosopher defined a point 'above' or 'below' the earth as one on a line that intersects the earth's surface orthogonally. On the spherical paradigm of the earth, to which we are accustomed, this definition is of limited consequence: because a sphere has surface in any direction, an object anywhere in space will always appear at the zenith of one point on the sphere and at the nadir of another point on the same axis. This definition of 'above' and 'below' makes a world of difference for a flat earth, however. Generally, two types of orbit are conceivable around a thin flat surface: one that takes the object directly over or under the surface, so that it appears at the zenith or nadir of places on the surface, and one that takes it higher or lower than the surface without ever passing directly overhead or underneath it. If the orbit is orthogonal to the surface, the object necessarily passes directly above and below it, but for each orbit there is an inclination at which it will no longer do so. The wider the orbit, the less inclination is needed for it to never pass directly above or below the earth.

The difference between 'directly below' and 'at a lower level but around' is of the essence, but presents a lexical conundrum. Ὑπὸ primarily means the former, but Greek as well as English seem to lack a handy word for the latter. The word 'around' in Anaximenes' fragments arguably communicates not just the notion of a circular orbit, but the specific case of an orbit that is wide or inclined enough to not cross over or under the earth's surface.

It now becomes apparent that the fundamental problem tackled by Anaximenes may have been one of scale or proportions. The issue at stake with a cosmic orbit was not just its angle, but also its radius and the object's size relative to the earth. If the flat earth is large in relation to the sun's path, the sun is likely to be directly above the earth for much of the day and directly below it for much of the night. Conversely, a comparatively small earth inside a wide solar orbit creates a situation in which the sun is rarely, if ever, directly above or below the earth, even though it may seem to be so from the ground. The contrast between the two scenarios is easily visualised in a diagram by projecting subsolar and suprasolar

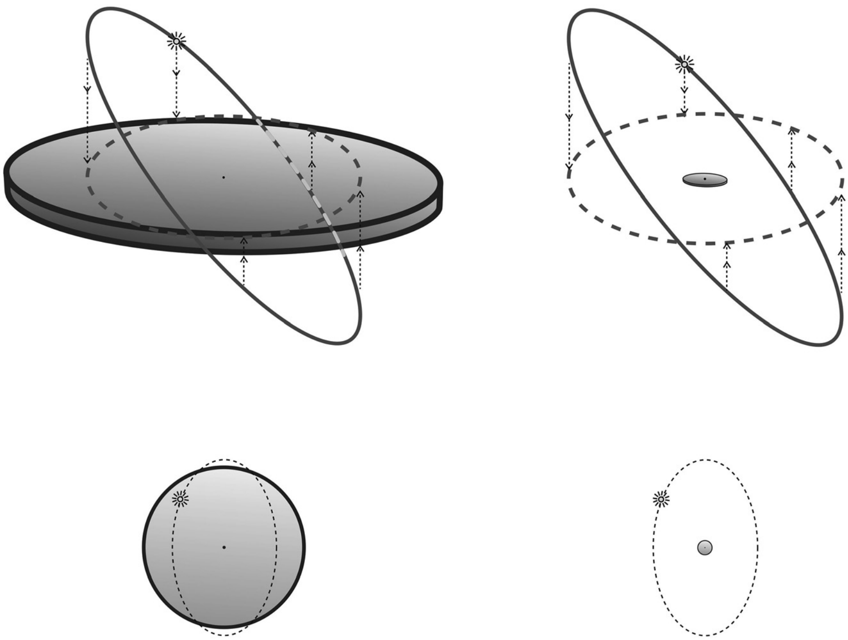

Figure 3: The sun moving mostly 'above' and 'below' a relatively large flat earth (left) and completely 'around' a relatively small flat earth (right) – a new way of understanding Anaximenes? Top: oblique view. Bottom: view from above. In each image, the north is to the right. Shown for the equinoxes. © Marinus Anthony van der Sluijs/Seong Hee Jo (2024).

points orthogonally to the flat earth's plane for a single day and night, especially as seen from above (Figure 3).

Anaximenes' challenge was then to determine which of these two types of orbit the stars and planets follow in their diurnal revolutions. A naïve observer ignorant of the earth's size or sphericity has to guess whether the sun passes directly underneath any place on the earth. The only time when he can be confident that the sun is directly above the earth is when it appears at the zenith. This solely happens in tropical regions: once a year, at the summer solstice, on the tropics of Cancer (23.5° N) and Capricorn (23.5° S) and twice a year at latitudes in-between, on days varying with the latitude – the equinoxes in the case of the equator. In the real world, this is always at noon; on a flat earth, it could be at any time of day, depending on location.

Was Anaximenes in a position to know about the zenith appearances from anyone's direct observation? There is no evidence for that. The tropic of Cancer is not far south of Aswan (Egypt). It is unclear when the knowledge first reached Greece that the sun appears overhead in southern Egypt at the summer solstice. Nor could the Ionian have worked out in theory that such a place exists on Earth without knowing the earth's size or globularity. The flat-earth philosophers must have regarded the angles between the astronomical rotation axis, the sun's orbit and the earth's surface as universally fixed. From this, they would have inferred that the pole appears higher in the sky as one moves northward and lower for observers further south, and that the reverse is true for the sun's noon position, for any given day. They would thus have had a primitive concept of latitude, superficially consistent with reality even if predicated on the falsehood of a flat earth. Any travellers' reports of the different altitudes of the pole and the heavenly bodies in places north of the equator could have been provisionally explained in this way.[75] However, this crude latitude could not be quantified without correlating the altitudinal values with distance on the ground – and there is no proof that the Greeks of Anaximenes' time had attempted that feat. Anaximenes probably had no way of telling whether the earth's disc extended far enough in any direction to directly underlie the sun by day or overlie it by night at any time of day or year. If the meaning of his 'around' is correctly established here, he would have come down against that possibility, claiming that the sun only *appears* to be directly above or below the earth.

The whole matter would have been unrelated to disappearance below the horizon, which was taken as read. Anaximenes' genius would have lain in his momentous insight that movement of the celestial bodies at great distances from the earth takes them to higher levels than the earth but not directly above it and lower levels than the earth but not directly below it, coinciding in the sun's case with day and night. Modern exegetes who accepted that 'around the earth' referred to circular orbits did not, as a rule, suspect that this description stood in antithesis to passing through the zenith or nadir of anywhere on Earth. The single exception would be McKirahan, who was adamant that the orbit 'around' the earth was one "whose diameter is large enough not to intersect the sea of air beneath the earth".[76] His diagram (Figure 2) duly shows a solar path with a noon position well beyond any terrestrial zenith, but there was a drawback: "This model cannot account for all the visible stars, unless the spherical segment cuts through the column of air beneath the earth."[77] That air had to be dense enough to preserve the earth's "serene poise" and so McKirahan limited the sky with such orbits to the hemisphere north of the sun's

75 Couprie (2018, 112); Panchenko (2015, 416).

76 McKirahan (2010, 56).

77 Ibid., 56 n.15.

path. For Couprie, this flaw disqualified the model altogether,[78] but that verdict is premature. Column or not, the element of air would naturally extend no further anyway than the surrounding spheres of the sun and other 'stars'. And when Couprie disputed McKirahan's stance on 'under',[79] it was lost on him that McKirahan was deliberately modifying the horizon-bound definition of 'under'. In sum, McKirahan's exposition can be fairly upheld with a sphere, though it could still be that Anaximenes tilted the earth instead of the pole.

Two or three 19th-century scholars are apparently the only ones to have thought these nuances through properly. Zeller mused:

> Nun könnte es freilich scheinen, wenn sich Anaximenes den Kreisabschnitt, welchen die Sonne vom Morgen bis zum Abend am Horizont beschreibt, zur vollständigen Kreisbahn fortgesetzt dachte, habe er nothwendig denselben unter der Erde durchführen müssen. Aber wenn dieser Kreis auch die Ebene unseres Horizonts schnitt, führte er desshalb doch nicht unter die Erde, d. h. unter die Grundfläche der Walze, auf deren oberer Seite wir uns befinden …, sondern bildete einen um diese Walze zwar in schiefer Richtung, aber immer noch seitlich herumlaufenden Ring …[80]

Berger expanded:

> Recht eigentlich unter die Erde konnte ein Gestirn nur kommen, wenn sein oberer und unterer Culminationspunkt senkrecht über oder unter irgend einem Punkte des Durchmessers der Erdscheibe stand. Die Bezeichnung der Bewegung um die Erde war auch für diese Art der Bewegung zulässig, sie konnte aber als gewählter Gegensatz auf Gestirne angewandt werden, die nie eigentlich unter die Erdscheibe kamen. … Nahm man, wie es geschehen musste, die schiefe Sphärenstellung an, so kam es also auf den Winkel des Sternkreises mit dem Horizonte, auf die Grösse des Erddurchmessers im Vergleich zu dem Durchmesser des Sternkreises, auf die Declination des Gestirns an bei der Wahl des Ausdrucks für die wirkliche Bewegung, namentlich bei der Frage nach der Möglichkeit einer Bewegung unter die Erde. … Die Sonne, sagte der Milesier nach dieser Angabe, geht nicht unter, weil sie unter die Erde kommt, sie wird vielmehr nur von den höher gelegenen Theilen der Erde verdeckt, dem Blick entzogen, und durch den eintretenden grösseren Abstand von uns.[81]

The variant reading 'above' in Diogenes no longer presents a problem if it contrasted movement *directly* above the earth with movement higher than the earth but around it. Recall also the tension between pseudo-Plutarch and the other witnesses. According to pseudo-Plutarch, Anaximenes' stars "revolve under the earth and around it". If this can be lent credence, meaningful accommodation is attainable. Following Röth, it may be that these words just meant to validate both terminologies: 'under' in

78 Couprie (2018, 101, 102 n.13, 110–13); (2015, 7–9, 24).
79 Couprie (2018, 111); (2015, 8).
80 Zeller (1876, 227 n.1) (English: 1881a, 275–6 n.2) = (1919, 327 n.4).
81 Berger (1894, 28–9). Sartorius (1883, 34) probably understood as much.

the sense of 'below the horizon' but at the same time 'around' in the sense of circular orbits bypassing any terrestrial nadir – and *mutatis mutandis* the same for pseudo-Galen. But there is another possibility. Note that the double movement applies to *all* 'stars', not only the sun. Therefore, it can be read as an acknowledgment that there are some bodies that pass perpendicularly below the earth, while others go 'around' it, in the sense defined here. Presumably, the ones moving 'around' would be in the majority and include the sun, moon and planets, which are confined to the ecliptic band. Some fixed stars, however, approach the zenith of the Mediterranean sky. One example is Vega (α Lyrae) in summer. Anaximenes may have allowed by analogy that other fixed stars can move directly below the earth. Again, without knowing the size of the earth it would have been difficult to identify any stars meeting that criterion.

It is marginally possible that Anaximenes also countenanced a combination of the two movements, 'above/below' and 'around', in the same celestial body. On human timescales, the fixed stars always follow the same paths through the sky. They rise and set at fixed points on the horizon, be it at different times of night or day. Not so the sun, moon and planets. The places of sunrise and sunset are due east and west at the equinoxes, but shift north during summer and south during winter. Without exact figures for the sizes of the earth and the sun's orbit, Anaximenes may have considered that the sun can appear perpendicularly above or below some part of the earth for all or part of the year. For example, this would be the case in Couprie's diagram (Figure 1). This necessarily illustrates a day between the spring and autumn equinoxes, when the sun rises and sets north of the equator. As it assumes a relatively small solar orbit, it shows the sun then 'around' the earth near midnight and 'above' it at midday. Anaximenes probably postulated a wider orbit than that, but maybe not so wide that it would not in some season take the sun 'above' or 'below' the earth at noon or midnight, if not longer. It may be that subtlety, for the sun and perhaps the moon or some of the planets, that pseudo-Plutarch preserved in a fuller version of the *doxa*. At any rate, none of the Greek versions need be corrupt and all can be consistent.

5.4 Night Cap

As a curiosity in cultural astronomy, some societies likened the sky to a hat. In Qīnghǎi (China), the Amdo Tibetans regarded it as a hat decorated with the sun.[82] And among the Ngaju, a Dayak group of central Kalimantan, it was the conical hat mainly worn by women that symbolised the sky, "und wie der Hut den Menschen

82 Hermanns (1955, 61).

deckt, so der Himmel die Erde."[83] Was Anaximenes' simile of a felt cap or hat (πιλίον) also tied up with the shape that he assigned to the sky?

In a spherical heaven, stars diurnally move in parallel circles with diameters decreasing from the equator to the poles. Boll held that Anaximenes took a step back by abandoning Anaximander's spherical heaven in favour of a purported Babylonian view that the stars move in parallel circles with the same diameter.[84] He based this on an interpretation of Anaximenes' metaphorical hat as a combination of top hat and calotte. Although the two illustrations of such a hat that Boll referenced[85] look more like hemispherical caps, he was probably thinking of something like a turban.[86] The cylindrical part would have comprised the paths of the rising and setting bodies, the cap the circumpolar sky. In fact, such a cylindrical heaven of stars is not impossible for Anaximander. None of the sources demand it for him or Anaximenes, however.[87] Boll failed to prove that Anaximenes' sky was not spherical or hemispherical.[88]

Anaximenes may have chosen the image of a hat on the basis that its rim surrounds the head on all sides like an orbit, without an implication for the shape of the sky. It should need no argument that most headgear can be worn – and turned – at an angle to the crown of the head. If the rim is wide enough, it may be at no point perpendicularly above or below the head.

5.5 Far Out

The rôle of distance in the sun's nightly disappearance, as noted by Hippolytus, remains to be accounted for. Kirk and Raven brushed it off as "a doxographical addition",[89] but this approach is intellectually lazy. The question to ask is: a 'greater distance' (πλείονα … ἀπόστασιν) compared to what?

Long before Panchenko did so for a non-setting sun, Goebel sought an explanation in the idea that Anaximenes located Greece south of the earth's centre.[90] If the sun orbited around an axis joining that centre to the celestial pole, it would always be closer to Greece at noon than at midnight. This cannot have been Anaximenes'

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83 Helbig (1941, 60).

84 Boll, in Kopff (1914, 361 n.).

85 Baumeister (1885, 506 figure 547, 642 figure 713).

86 Guthrie (1962, 138).

87 van der Sluijs (2021, 283–5); Couprie (2003, 221–8).

88 Hölscher (1954, 413; cf. Guthrie (1962, 138 n.2); Couprie (2018, 102, 119–20)) misread Boll as keeping the celestial bodies above the horizon.

89 Kirk and Raven (1963, 156).

90 Goebel (1910, 37).

intention, however; he must have situated Greece – with Delphi – at the centre to 'save the phenomena' of the seasons.[91] He would see the sun rising due east and setting due west on the equinoxes, dividing the year in halves of equal length – one with shorter days and one with shorter nights. If he had lived south of the centre, he should have seen more days in the year with the sun rising and setting to his north than to his south, which was plainly not the case.

Earlier, Teichmüller had had a neater suggestion.[92] The sun in its descents and ascents must pass along the earth's sides, the thickness of which may matter. The time spent between the earth's top and bottom – below the horizon – would count towards the night. Hence the sun is inevitably closer to 'us' on the surface at noon than at midnight. This seems feasible, but how thick could this earth be without violating Anaximenes' characterisation of it as wafer-thin like a leaf?

Berger speculated that Anaximenes was supplementing his basic explanation for the night with an annual variation of distance, culminating in winter when the nights are longest. For any location outside the tropics, the summer solstice is the time of year when the sun at noon is closest to the zenith and the winter solstice that when it is furthest from it. In this spirit, Berger imputed to Anaximenes the wordy understanding that "das Maass der Verdeckung der Sonne mit dem Abstand der dem südlichen Wendekreise zustrebenden Sonne von dem Zenith unseres Erdhorizontes zunehme."[93] This, too, can be visualised using Figure 1, by sliding the sun's orbit down along the celestial axis while keeping its diameter the same.

On a separate occasion, Berger wondered if Anaximenes could have heard about the 'midnight twilight' of the far north and seen it as evidence that the sun follows a tilted orbit, raised enough in summer for the glow to extend even above the northern horizon.[94] He seemingly overlooked that that might shed another light on Hippolytus' 'distance': night is contingent on an adequate vertical distance between the horizon and the sun below it.

The midnight twilight, which gives more 'bright nights' the further north of 49° N, was perfectly comprehended from the early Roman imperial period on.[95] Hearsay about it may have circulated in Greece by the late 7th century BC, if it informed the

91 Compare Couprie (2003, 195–7) for Anaximander.

92 Teichmüller (1874, 102–3).

93 Berger (1894, 29).

94 Berger (1887, 55 n.2, 100). Panchenko (2012, 47) put a kindred idea to a different use: Anaximenes would have been conscious of the true midnight sun and from that inferred that the sun's rising and setting, when seen, are illusory; the sun would have always orbited at the same height, with a seasonally varying radius. Downsides of this analysis were highlighted above.

95 e.g., Strabo, *Geography*, 2.5.42; Pomponius Mela, *The Situation of the World*, 3.6 (57); Pliny, *Natural History*, 2.77 (186); Tacitus, *On the Origin and Situation of the Germanic Peoples*, 45.1; *Agricola*, 12.

myth of Helios' nightly movement on the horizontal plane of the Ocean.[96] If the Greeks of the mid-6th century BC had learned that the phenomenon is exclusive to summer, Anaximenes could have been rectifying that myth: the god still moved along the earth's northern perimeter, but in air and at a depth below the horizon that varied with the seasons. And why, on a flat earth, was the midnight twilight not visible in the Mediterranean region like the normal twilight? Mythmakers could have turned to intervening fog or mountains, but that would be unpalatable to rationalists. Raised above the surface, an observer closer to the earth's edge would look further down into the space adjacent to the earth, where Anaximenes put the night sun. Such may have been Anaximenes' logic, but if the distance between 'us' and the sun was 'greater' only in comparison to northerners, why did Hippolytus not articulate that?

As argued, Anaximenes realised that the wider the orbit, the greater the chance that the sun is hidden by a portion of the earth's disc without physically being directly below it. Hippolytus could have simply meant to clarify that orbital difference, the distance 'having become' greater not at night, in winter or in the *oikouménē*, but in the new paradigm.

5.6 Anaximander Augmented

Where does this leave Anaximenes' relation to Anaximander? There is no need any longer for the unlikely proposition that he reverted to a more primitive, even mythological worldview. He would have endorsed his teacher's discovery of the earth as a full-fledged celestial body suspended in space. He would have concurred that all celestial bodies seen from Earth except the circumpolar stars complete their orbits in an invisible domain of space below sea level.

Pseudo-Plutarch opened Anaximenes' entry after Anaximander's with the word ὁμοίως ('similarly'), implying correspondence as well as difference. Couprie explained: "… the difference between Anaximander and Anaximenes in pseudo-Plutarch's version … is not … that the one believes that the heavenly bodies go under the earth and the other does not, but that Anaximander regards the heavenly bodies as fiery holes at fixed places of turning wheels, while Anaximenes has in mind fiery bodies (or leaves) floating on air."[97] Both posited circular orbits around the earth at an angle, but whereas Anaximander had the bodies revolve in fixed frames, Anaximenes made them do so freely.

96 van der Sluijs (forthcoming).

97 Couprie (2018, 117).

In Anaximander's theory, the sun's wheel is '27-fold' or '28-fold' the earth.[98] On the traditional understanding, this number represents the orbit's diameter, radius or even length expressed in earth diameters. Couprie reckons it to be misunderstood, reasoning that Anaximander should have deemed the sun to be quite small and much closer to the earth in order to make sense of places where it appears at the zenith on certain days:

> On a flat earth the sun must be nearby … We are so accustomed to the idea that the heavenly bodies are at great distances, that we take for granted that the ancient flat earth cosmologists shared the same idea.[99]

Is that tenable? As seen, pre-Socratic philosophers should have had a theoretical expectation that the altitude of the pole increases as you go north and that of the noon sun, for a given day, as you go south, with shortening of the shadow cast by a gnomon. A flat earth additionally requires that the sun each day rises and sets instantaneously for all locations,[100] with at best a tiny difference near the edges that face sunrise and sunset. Exploration of far-flung regions would have revealed latitudinal variation of daylength before yielding empirical evidence – from southern Egypt – for the sun at the zenith. Couprie elsewhere observed that "the argument of time differences" was absent from pre-Socratic discourse.[101] One can second Panchenko:

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98 Hippolytus, *Philosophical Teachings*, 1.6.5, trs. Laks and Most (2016a, 286–7); Aetius, *On the Physical Opinions*, 2.20.1; 2.21.1, in Eusebius, *Preparation of the Gospel*, 15.23.1; Stobaeus, *Anthology*, 1. 25.1c, trs. (2016a, 296–9); pseudo-Galen, *Philosophical History*, 14, ed. Kühn (1830, 274–5) = Charterivs (1638, 36); Theodoret of Cyrrhus, *Cure of the Greek Maladies*, 1.97; 4.22, tr. Scholten (2015, 182–3, 324–5); cf. Couprie (2018, 78). Theodoret attributed this size also to Anaximenes.

99 Couprie (2018, 82–3, cf. 35–41, 55, 78–97, 100, 102, 112); (2015, 6, 8–9, 27); (2011, 119–36), superseding (2003, 211–28). Thibodeau (2017) proposed that Anaximander's numbers described the orbits' lengths, measured in units equal to the earth. They would primarily represent real distances in space and secondarily a method to visualise the relative positions of the sun, moon and earth in order to calculate the exact duration of the synodic month. Couprie (2018, 93–5) backed only the latter, the model being calendrical but not cosmological, and hardly compatible with the sun's angular size. Note that his "night-plus-day (a nukthemeron)" must be read as 'a night or day (half a nukthemeron)' (compare Thibodeau 2017, 102). Kiessling (1914, 849, 851) similarly claimed stellar proximity to a flat earth: "Anaximenes stellt sich ja die Erde vor als eine im Verhältnis zum Kosmos ungeheuer groβe Kreisplatte" to ensure that the pole be vertically over a point on Earth.

100 e.g., Ptolemy, *Mathematical Syntaxis*, 1.4, tr. Toomer (1984, 40–1); Pliny, *Natural History*, 2.72–3 (180–1); Manilius, *Astronomy*, 1.228–9; Martianus Capella, *On the Marriage of Philology and Mercury*, 6 (591–2).

101 Couprie (2018, 42–3, cf. 250). According to the fragment cited above from Hippolytus, Archelaus used the earth's presumed bowl shape to explain why sunrise and sunset happen at different times in various locations. Couprie, like Fehling (1985, 200) and many others, was dismissive, arguing that it produces the opposite effect to reality: on a concave earth, sunrise would be seen earlier in the west than in the east. Panchenko (1999, 22–7, 36–8) is probably right that Archelaus relied on records of

> Anaximander … was a founder of Apollonia on the Black Sea. But even the difference between the longest days in Apollonia and Miletus is much less than one hour. Such a difference could have passed unnoticed.[102]

Panchenko plausibly argued that this nescience enabled Anaximander to maintain the fiction of a flat earth. It would have been during Anaximenes' lifetime, when the clepsydra and more informative *in situ* observations were available, that "the Greeks firmly recognized the fact that the lengths of the longest day or night differ according to what we now call the latitude of the place."[103] Diogenes named Anaximander as the inventor of gnomonics.[104] Pliny fingered Anaximenes instead.[105] Either way, it seems prudent, on current knowledge and *pace* Couprie, to reiterate what was mooted above – that data from Egypt's far south were still beyond Anaximenes' reach. And as long as distance on the ground was not factored into the calculations, it was by no means unassailable that the sun and stars were near.

Should the conventional interpretation as 27 or 28 earth diameters be accurate after all, the sun would always be 'around' the earth, as defined above for Anaximenes. As Berger put it:

> Für Anaximander z. B., dessen Erdumfang … im Verhältniss zum Umfang der Sonnenbahn sehr gering war, hätte der Ausdruck, die Sonne gehe unter die Erde, nur eine scheinbare Stellung bezeichnen, nur eine bildliche Bedeutung haben können.[106]

The semantic implication for the words for 'over', 'under' and 'around' may just not have dawned on Anaximander. Anaximenes would have still lacked reliable numbers to determine the sun's distance and size, but developed a better feel for the various possibilities. Displaying keen insight in perspective, he would have sensed that the sun must be sufficiently far removed for it to not pass perpendicularly above or below the earth. By spelling that out, as far as the language permitted, he would have improved on Anaximander's *Weltanschauung*. One might say that if

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solar eclipses that occurred at sunrise or sunset in Greece, but well after sunrise in eastern lands or before sunset in western lands. However, Panchenko needed a convex earth to make that work. Could Archelaus have perceived that eclipses move east with the moon's shadow and assumed a velocity high enough to imply that the sun does rise earlier in the west, consistent with the bowl model? Whatever the case, he lived long after Anaximenes.

102 Panchenko (2015, 424). Similarly for the height of the pole: Fehling (1985, 201).

103 Panchenko (2015, 425, cf. 412).

104 Diogenes Laertius, *Lives*: *Anaximander* (2.1), 1.

105 Pliny, *Natural History*, 2.78 (187). Cf. Wöhrle (1993, 11).

106 Berger (1894, 28).

Anaximander discovered space, it was Anaximenes who fathomed its immensity or the earth's relative smallness.[107]

The spherical model of the earth, which was widely embraced in the Hellenistic era, incorporated the knowledge that there truly are places where the sun appears in the zenith or nadir on certain days of the year, at noon and midnight. The old rival scenarios of the sun above-and-below the surface and around-but-not-directly-above-and-below the surface were then confidently harmonised. In antiquity, these minutiae would have been as prone to misunderstanding as they are now. The failure to grasp how a wide orbit around a flat earth changes the meanings of 'above', 'below' and 'around' qualifies as another instance of what Couprie so aptly called the 'spherical earth bias'.[108]

6 Egyptian Links

It has been said that ancient Egyptian astronomy "zeigt … genau denselben Grad von Primitivität wie die ältere griechische Astronomie".[109] Röth, who had relevant credentials, developed an elaborate theory of Egyptian influence on ancient Greece. He suggested that Anaximander via a prolonged presence of Thales in Egypt acquired the doctrine of a turning cosmic sphere that: was enclosed by an infinite expanse of water; was dotted with the fixed stars; and itself contained the sun, moon and planets in smaller rotating spheres, the flat earth alone resting on water at the centre.[110] One of Anaximander's innovations would have been that the earth floats freely in air.[111] Zeller took issue and therewith set the tone for ensuing generations. A recent review concluded that he did not, in hindsight, have the edge, but that up-to-date Egyptological literature is yet to be mined on the subject.[112]

Given that Egyptology was still in its infancy in Röth's time, it is not surprising that much of his information is now obsolete. Nonetheless, something of his premise may be salvaged when converted into modern terms. The realisation that

107 Al-Jāḥiẓ (*c*776-*c*868) conveyed a teaching of Anaximenes that the sun is smaller than the earth – *Kitāb ad-Dalā'il wa'l-I'tibār 'alā l-Ḫalq wa-t-Tadbīr* (*Book of Proofs and Reflection Regarding Creation and Divine Governance*), in Daiber (1980, 399). If truthful, this is inconsequential for the subject at hand without knowing Anaximenes' figures for the earth's size or the sun's distance. Perhaps he upheld Anaximander's distance between the centres of the earth and sun, but with a smaller sun or larger earth to make it go 'around' the earth as understood here.

108 Couprie (2018, 82).

109 Lange and Neugebauer (1940, 73); cf. Warburton (2016, 80).

110 Röth (1858, 118–27, 129, 131, 135–53, 157, 160).

111 Ibid., 152.

112 Forster (2015, 141–52, 157).

the sky homogeneously envelops the earth on all sides need not have come out of the blue with Anaximander. The Egyptians did not recognise the region below the horizon as a continuation of the sky, but did have the concept of the dark and uniform ocean Nu(n) (*nn*, *nw*(*n*) or *nnw*) stretching in every direction around the 'known' world of earth (Geb or *tз*), air (Shu) and sky (Nut or *pt*). The celestial bodies only moved – on water or land – in the inner realm near the surfaces of the firmament: under Nut's belly when visible and in the Duat (*d*(*w*)*зt*) when invisible. This last region seems to have been contiguous with Nun 'inside' the body of Nut.[113] By merging the all-encompassing watery abyss, Duat and firmament, Anaximander would effectively have released the celestial bodies into unbounded space. So far, so good.

The case is less straightforward for the paths taken by the sun and other objects. Scholars commonly think that the Egyptians – of the Old Kingdom no less – ideated continuous circular orbits at an angle above and below the flat earth, through a subterranean Duat.[114] Yet the alternative system of a return path to the east *above* the day path, through an invisible domain inside Nut's body, may have held far more sway than generally admitted.[115] A comparison with Greek ideas then falls flat.

Nor need the traffic of ideas only have been one-way. A Ptolemaic scene from Philae depicts two arched Nuts stacked above the earth, while one from Dendera features three. Röth resolved these as "mehrfachen Himmelsgewölben", "offenbar für die Fixsterne und für Sonne und Mond".[116] Following Couprie's thought-provoking thesis, these were probably attempts to integrate into conventional Egyptian iconography Anaximander's theory of multiple wheels or orbits around the earth, which were representative of depth in the universe.[117]

Be all that as it may, there is no indication that the Egyptians occupied themselves with the geometric problem of whether or not the heavenly bodies pass perpendicularly above and below the earth. It fell to Anaximenes, if the present argument holds up, to discern that distinction.

113 e.g., Allen (2005, 9); (1989, 10–13, 25); (1988, 3–7). Cf. Röth (1846, 143, 164–5, 170).
114 e.g., Allen (2005, 9); (1989, 13–14, 23–4); Krauss (1997, 65–6, 215, 277); Sethe (1928, 263). Cf. Röth (1846, 144, 146, 148, 165–8).
115 van der Sluijs (forthcoming 2); Piankoff (1934). Bilić (2021, 87) encountered this system in pseudo-Jerome (*The Cosmography of Aethicus the Istrian*, 1.14, tr. Herren 2011, 14–15), but struggled to understand it and missed its Egyptian background.
116 Röth (1846, 167); cf. Bonnet (1924, figure 3); Schäfer (1927, 114–15); Lange and Neugebauer (1940, 28 n.1). As early as 1802, Denon (1802a, pl. 129.5; 1802b, 240) had interpreted the figure from Philae as "l'espace dans lequel le soleil et la lune enveloppent la terre".
117 Couprie (2003, 231–7).

7 An Auroral Aspect

As mentioned, the midnight twilight of northern Europe – vaguely heard about – may have been behind an ancient Greek belief that the sun glides along the northern horizon at night without setting. So could the *aurora borealis*,[118] with the added advantage that it appears even at Mediterranean latitudes at intervals of 3–10 years on average. To the flat-earthers of the day, a sun so returning theoretically ought to produce persistent twilight visible even from Greece. The intermittent manifestation of the northern lights there directly on the horizon would give the lie to the existence of northern mountains hiding the sun, while signalling some momentary suspension of whatever normally prevented that display. In the naïve framework of myth, tolerable explanations may have been the god's arousal, opening of a portal or clearing of fog in the far north. Philosophers theorising the sun's descent in a circular orbit could have thought along the lines of elemental changes optimising the reflectivity of the northern air. No less an authority than Galileo (1564–1642) fell back on an Aristotelian exhalation of unusually rarefied air reflecting the sun's splendour on the earth's nightside as he coined the term 'northern dawn' (*boreale aurora*) for this light.[119] If this luminary of the Scientific Revolution could have misperceived the polar aurora as a queer type of twilight on a spherical earth, it is not preposterous to consider Anaximander and Anaximenes likewise taking it to be the sun illuminating the flat earth from below the horizon in the rumoured midnight twilight. It is not all plain sailing, however. The aurora's rarity precisely in summer would have thrown a spanner in the works. Together with its refusal to steadily go from northwest to northeast, the absence of a pronounced midnight twilight from the normal Greek summer sky could well have moved these men to leave it out of the picture.

Appendix: Two Christians on the Sun's Distance at Night

One pseudo-Justin, variously identified as Diodorus of Tarsus (d. *c*390) and Theodoret of Cyrrhus (*c*393-*c*460), offered solar distancing as the means to explain night on his flat earth.[120] His proof was self-defeating: the gradual disappearance of ships over the horizon only works with curvature, as they do not only appear to shrink but are also

118 van der Sluijs (forthcoming).

119 Gvidvcci (1619, 39), ghostwritten by Galileo; cf. Drake (1960, 53–4); Siscoe (1978).

120 pseudo-Justin, *Answers to the Orthodox*, 72, tr. Harnack (1901, 104).

cut off from below.[121] Perhaps to be on the safe side, this writer refrained from details about the sun's return path. If not one along the northern horizon, in the style epitomised later by Cosmas except for the mountains, he might have settled for one back up into the southern sky, behind the daytime arc. This had a respectable Egyptian pedigree, noted above, though pseudo-Justin's Alexandrian near-contemporary Didymus the Blind (*c*313-398) was derisive when mentioning what must be the same tradition.[122]

Didymus himself had no qualms with the prevailing Ptolemaic tenet of a solar orbit with fixed radius around a spherical earth.[123] He did in the same commentary write that the sun at night, though seemingly obscured, in truth keeps shining 'but comes to be far from us, way out of view'.[124] There is no mystery there, however.[125] The sun technically *is* one earth-diameter further away at midnight than at noon for someone on the surface.

None of this has anything to do with Anaximenes.[126]

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121 Schleicher (2014, 182, cf. 77).

122 Didymus the Blind, *Commentary on Ecclesiastes*, 13.2–5, eds. Binder and Liesenborghs (1979, 54–5). The impression of Schleicher (2014, 182, 191–2, 204, 265) that this involved a northern path is groundless.

123 Schleicher (2014, 71–4, 77).

124 "ἀλλὰ πόρρω ἡμῶν γινόμενος μακρὰν τῆς ὄψεως", Didymus, as above, 341.4–6, eds. Binder and Liesenborghs (1969, 128).

125 So, reluctantly, Schleicher (2014, 77).

126 *Contra* Schleicher (2014, 182, 192, 265).

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