Aristarchos Unbound: Ancient Vision

The Hellenistic Heliocentrist's Colossal Universe-Scale
Historians' Colossal Inversion of Great & Phony Ancients
History-of-Astronomy and the Moon in Retrograde!

I am restless. I am athirst for faraway things.
My soul goes out in a longing to touch the skirt of the dim distance.
O Great Beyond, O the keen call of thy ute!
I forget, I ever forget, that I have no wings to fly,¹ that I am bound in this spot evermore.²

Summary

Genuine ancient astronomers made repeated use of the fact that the human eye’s vision-discernment limit is ordmag $1/10000$ of a radian. Use of this key empirical figure is connectable (§F9) to all 3 of the huge astronomical scales attributed to the school of Aristarchos of Samos, the 1st certain public heliocentrist visionary. Evidence also suggests Poseidonios’ sympathy with (and enhancement of) this same vast heliocentric worldview (§F2), which entailed a universe a trillion times larger than the geocentrists’.³

A Muffia Vision

A1 Today, it’s widely supposed that the astronomy of Aristarchos of Samos⁴ (c.280 BC) was mostly theoretical; i.e., he is viewed within the constraints established by the fabulously logical reasoning of modern history-of-astronomy (hist.astron) on Greek science. For example, Neugebauer 1975 (pp.643) presumes that all the work attributed to Aristarchos has “little to do with practical astronomy”. The famous “Aristarchos Experiment” based its ratio of the distances of the Sun&Moon upon the half-Moon’s occurring ³² sunward

¹Likewise, the historian of things ancient has no temporal wings to fly into the past. He can experience bygone times only in his imagination. Rising from an evidential ground, he soars above it only by the strength of his inductive skills.

²From the Indian poet R.Tagore. This particular poem inspired Viennese composer Alexander von Zemlinsky to his most dramatic musical success: the first song of his 1923 Lyric Symphony Op.18. It should be stated explicitly that DR shares none of the mysticism of either artist. And I note that Dionysios the Renegade (c.300 BC), for whom I suggest (DIO 1.1 §1 fn 23) Aristarchos named the 365¹/₄ Dionysios calendar, based his philosophy ultimately upon hedonism. (Another part of the same Tagore poem contains the famous phrase, “stranger in a strange land”, now perhaps best known as an R.Heinlein sci-fi title. The phrase is not original with either Tagore or Heinlein. It is from Exodus 2.22 & 18.3. It also appears in Twain’s 1870 satire, “Goldsmith’s Friend Abroad Again”.)

³[Note added 2011: Trillion-factor based on cubing result of fn 72’s concluding ordmag-rounded calculation. (Without rounding: said factor will be an ordmag less.)] Rawlins 1985K proposes that the highly accurate Venus & Mars mean motion tables (major improvements to Aristarchos’ tables), underlying the Almajest 9.3 tables of those 2 planets, were originally designed for epoch Kleopatra 1 (~51/9/5). Chronologically, this is consistent with Poseidonios being among the promulgators of the original tables, whether or not based on his own work.

⁴Unlike most writers on ancient science, I use the Greek ending “os” (instead of the Roman ending “us”) for Hellenistic individuals’ names. (E.g., Hipparchos instead of Hipparchus. Of course, other DIO authors are free to spell as they wish in their own articles.) The particular situation that caused me to do this was the question: if scholars are so casual about endings that they unblinkingly refer to “Aristarchus of Samos”, then: is it equally OK to use “Aristarchos of Samos”? (Given Aristarchos’ revolutionary contributions, we note in passing that Samos was historically notorious for rebelliousness.)
of quadrature (eq. 4 below); but hist.astron-don Neugebauer 1975 (pp.642-643, quoted by Van Helden 1985 pp.6&167 n.8) claims that this is “a purely fictitious number” (part of a “purely mathematical exercise”), and that the data of a supposed lone extant Aristarchos ms., “On Sizes & Distances” — which DR ascribes to an otherwise unknown soon-after indoor mathematical pedant pseudo-Aristarchos — “are nothing but arithmetically convenient parameters [§3], chosen without consideration for observational facts which would inevitably lead to unhandy numerical details.” (One might as well straight-out call Aristarchos an idiot. Such pontifications by the ever-intolerantly arrogant Neugebauer-cult — formerly known here as the Mufa — themselves ignore the crucial significance of a glaringly “unhandy detail,” the demonstrable falsity of the long-time attribution to Aristarchos of solar dis-sizes — grossly overblown unempirical 2° solar diameter. It is not a JHA-scorned modern novitiate, but no other than the immortal Archimedes, who says [and see additional confirmation at fn 33] that the real Aristarchos got-it-right: §C1 item [a].) Similarly, on 1984/6/28, O.Gingerich astonished a small Zürich gathering (including van der Waerden, myself, my wife Barbara, and others), by supposing aloud that Aristarchos’ heliocentricity was not really a full-fledged theory: perhaps he’d merely broached the idea one day while chatting with another scientist. (See also fn 70.)

A3 But I must call a brief interlude at this point, in order that the reader not miss the weird inversion going on here in §A1&A2, the Neugebauer-overall-ancient-astronomy-conception’s perversity-pinnacle: rebeld&heliocentrist-pioneer Aristarchos was a non-observating, while go-along-geocentrist-data-faker Ptolemy was antiquity’s

5 Indo-Neugabeuer 1975 p.642 astonishingly claims that “one would be lucky to determine the night on which dichotomy falls”. Contra this (§Kp & fn 19), sharp-eyed descern lunatan lunatics whenever — as Aristarchos 3°, as DR & K-Pickering have 1°-hand veried outdoors 100s of times.

6 DR deliberately chooses the very phrase banned from the JHA by Lord Hoskin & O.Gingerich, whose political circle is dedicated to handing out AAS medals to those who got-it-wrong on Ptolemy’s fraudulence. (See the typically entertaining JHA editorial statement cited here at fn 17 & fn 64 [and specially placed on-line by DIO at www.dio.org/JHA.htm#ggss]. And note its debts to O.Neugebauer & O.Gingerich’s “fn 20.”) Evans 1992 p.68 still takes the pseudo-A 2° solar diameter bang so seriously that this author of Oxford Univ Press’ History and Practice of Ancient Astronomy draws overetn — not to mention perceptive — conclusions about the evolution of ancient astronomy during its two most productive centuries. (The usual for culists who think great ancient astrnomy only flowered with the faker Ptolemy.) See also fn 16.

If heliocentricity alone is held not to prove that Aristarchos had a planetary theory, we may ask what Ptolemy meant by (Heath 1913 p.304) heliocentric “saving the phenomena”? If we merely consider Earth & Sun, heliocentricity causes no simplification of theory — but (§A5) the elimination of epicycles does accomplish this. For years, such an obvious point was implicitly understood by able historians. But, with modern-pal-archons’ advent, acceptance of (or merely grasping) even elementary ideas has come to require awesome mental struggle.

8See DIO 6 §K11, which relays Levine’s spoof of his own WashMonthly’s penchant for conjecture, chaiting that other writers reading WM accounts of their output “find themselves espousing ideas they’ve never even of, much less agree.”

9Ptolemy’s fraudulent tendencies did not end at mere fabrication of data. He had also a proclivity for suppressing all mention of inconvenient facts. E.g., when he pretended (Almajest 3.1) that the solstices of Aristarchos & Hipparchos were consistent with the Hipparchos PH solar theory (Rawlins 1991W §K10) adopted for the Almajest, he suppressed (DIO 1.1 §A5) the time of each of these 2 solstices, and no other, of the score of equinox-solstice data provided thereabouts — thereby hiding the fact that each disagreed with said theory. (Each by the same amount: minus 1°/4.) Likewise, to

ABLE observer 10 For once, analogies fail me. No other fantasy in scientific historical analysis has ever been so Orwellianly wild. If some oddities are more unexceptionable than others, then this one is uniquely unique.

A4 Only in recent years have glimmers been detected (e.g., van der Waerden 1970 & Rawlins 1987) indicating that an ancient heliocentrist empirical 11 programme existed. The analyses presented below are part of the fleshing-out of this realization. We have just (§A) sampled now-accepted Mufa Wisdom on this subject, but the depth & persistence of the comedy may not have been fully appreciated. Thus, desiring not to deprive readers by inadequately mining this rich vein, I will here quote from the widely-acclaimed book of history of astronomy archon A.van Helden, Measuring the Universe (1985), which embodies and disseminates Mufa orthodoxy in such matters (pp.9-10, emph added):

[the Aristarchos Experiment] addressed only the problem of the sizes and distances12 of the two great luminaries [Sun & Moon]. No comparable geometric methods, however inadequate by our standards, were at hand for determining the sizes and distances of the other heavenly bodies. . . . he [Aristarchos] chose convenient [DR: this astoundingly uncomprehending word is taken straight from Neugebauer: §A1] upper limits for cosmic distances [eq. 14 here] . . . very little astronomy was involved . . . . However, [Mufa] scholars have discovered much about Hipparchus’ achievements . . . and how he improved on Aristarchos’ approach to the problem of sizes and distances.

Comments on these precious Van Helden 1985 remarks follow: A5 There is no sign here or elsewhere (e.g. fn 70) of Mufa appreciation for the critical point (made prominent in Rawlins 1987 and assertively detailed in Rawlins 1991P) that heliocentrists such as Aristarchos obviously knew the planets’ mean distances from the Sun in AU (merely the ratio of epicycle/deferent radii for inner planets, inverse for outer planets), since the elimination of epicycles was, after all, the prime (Occamite) motivation for converting to heliocentricity! (See fn 7.) This is perhaps the most crucial achievement of (as against measurement: §1 fn 9) made by anyone in ancient astronomy. (See next.

10 See, e.g., the bizarre attempt at Neugebauer 1975 p.284 (shamelessly followed by, e.g., Evans 1992 and Evans 1998 pp.273-274 & n.32 and even by Dambis & Effremonn 2000 p.133 [which was reffered by Evans]) that Ptolemy was a better observer than Hipparchos. Obvious to the 2 mens’ relative errors, random & systematic: Rawlins 1999 §§E3-E4. This particular hyper-inversion (started by Vogt 1925) is based merely upon the fact that semi-popular Hipparchos Cummomly uses roundings which are much more crude than those in the Catalog or those in Hipparchos’ declinations (Almajest 7.3). Furthermore, these apologia utterly and entertainingly conflict with those emitted by Huber (DIO 2.1 §JH, Swerdlov 1989, Grahohoff 1990, & Gingerich 2002, who contend that Ptolemy’s greatness in data-reportage was shown not at all by his alleged observations’ superior accuracy but rather through the intellectual projection by which he either fudged his inferior observations or replaced them by forgeries from theory! Question: Does an intellectually healthy and open community leave itself open to toady-spoofing by getting into such pretzel-thought?

11 Despite the warning in §P1, Gingerich 1992K p.105 nonetheless persists in stating that there was “an absence of proof” of heliocentricity even as late as the 16th century. This though Gingerich 1992K (earlier on the same page) notes that the outer planets’ motion exhibited a peculiarity as cohesive as the inner planet oddity cited at Rawlins 1991P §B1. (Uncited by Gingerich 1992K.)

12But distances are never computed in pseudo-A’s “Sizes & Distances.” (See Neugebauer 1975 pp.636, 639, & 643. Also Rawlins 1991W fn 220. Scrupulous and able mathematical analyses of this work are available by Heath 1913 data and Berggren & Sidoli 2007.) Perhaps realization of the contra-outdoor-sky results (§C1) of such calculations stopped pseudo-A from continuing his ms.
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§2 item [c], Rawlins 1987, & Rawlins 1991P.) Yet one looks in vain for mention of it in classic Mufaa output, including Neugebauer 1975 & Van Helden 1985. Centrist historians have long insisted that Greek ephemerides did not exist until at least Hipparchos’ time. By contrast, DR suggests that it was the onset of planetary tables in Greek science, possibly even as early as 4th century BC, which caused the conversion of intelligent scientists to heliocentrism, since planetary tables inevitably exhibited with rigid fidelity — elements of the “solar” motion in each and every planet’s model. (See Rawlins 1987 pp.237-238.)

A6 We find (as at Neugebauer 1975 pp.643 & 646) not a hint of the source of Aristarchos’ 10000 AU distance to the fixed stars (eq. 14), namely, the invisibility of stellar parallax for a heliocentric Earth-motion (§B2). This is obvious to any scientist worth the name. (Most understand the point immediately.) It is implied in the ancient work, the “Sand-Reckoner” (Archimedes p.222). The point is regarded as too obvious for elaboration by, e.g., van der Waerden 1963 (p.203). (By contrast, Neugebauer 1975 p.643 says that the 10000 AU radius Aristarchan universe reported by Archimedes p.232 has “as little to do with practical astronomy” as Aristarchos’ Experiment: eq. 4.) B.Rawlins wonders if selling putative Babylonian originality and genius has led Mufosi into denigrating Greek empirical work occurring before the central Babylonian astronomical texts’ era.) And this realization is (along with §5) another point which is absolutely critical to understanding Aristarchos’ vision, as well as representing the crux of the two-millennium-long (!) heliocentrist-vs-geocentrist debate — the greatest controversy in the history of astronomy, ranking with the (far briefer) natural-selection fight as one of the focal points of the rise of science and rationalism. (I.e., the Mufaa’s obsessive pretense, that geocentrist astrologers were brilliant, is glorifying the side that suppressed the actual great scientists of their time. Even the Roman church isn’t trying to cast those popes & cardinals as supposed Galileo as the actual top intellects of the medieval helio-vs-geocentrist dispute. So, in the field of outrageous historical-revision-apologia, the Mufaa outdoes even the master.)

A7 The claim that Hipparchos “improved” heliocentrist Aristarchos’ measure of the universe is particularly curious, since Hipparchos and other geocentrist probably put the stars at roughly Ptolemy’s distance (ordmag 10 AU), vs. Aristarchos’ ordmag 10000 AU. (See §E5. Actual distance of Proxima Centauri = 270000 AU.) In brief, Mufosi 12 regard it as just a meaningless coincidence that heliocentrist proposed the biggest ancient universe. This achievement, of the finest ancient scientists, is passed off as just primitive, perhaps

12 [Recently, O Gingerich has been trying to cope with this point. Without citation of DIO. Again.]

13 Van Helden 1985 p.19 appears to credit Hartner with the discovery that Ptolemy’s 19-to-1 Sun/Moon distance ratio was taken from Aristarchos, by quoting Hartner 1980 p.26 before quoting R.Neptune 1977 p.199 (see also p.173 and R.Neptune 1973 pp.382 & 384) with the same result. (Actually, the discovery of this revealing coincidence goes back at least to Delambre 1817 2:207. As suggested here at §E5: the coincidence may mean nothing more than that the resulting rs was the lowest value then current among competent [read: heliocentrist] scientists, which made it current enough even with geocentrist that it survived. It is also a fun coincidence that the Aristarchan ratio 19 (eq.9) helps set up a neat fit for Ptolemy’s geocentric nested-sphere scheme. Regardless, the implied solar parallax still survived in Tycho’s work — at the dawn of modern astronomy. Given that Tycho openly branded Ptolemy a plagiarist [DIO 1.2 fn 154]: which of the 2 men [Aristarchos & Ptolemy] is more likely to have been the one Tycho trusted, when Tycho adopted this [inaaccurate ratio]?) The Hartner-RN citation sequence might be accidental. What is certainly not accidental is the total omission, from the Van Helden 1985 discussion of Eratosthenes, of 2 prominently published DR discoveries regarding the ancient’s work. (DR’s name does not even occur a single page of Van Helden 1985. Standard for Mufaa archons’ output.) Van Helden 1985 p.5: “Since we do not know the precise length of the stade [Eratosthenes] used, it is fruitless to speculate on the ‘accuracy’ of his result. Suffice it to say that beginning with Eratosthenes the size of the Earth was known to the right order of magnitude.” Suffice it also to say that Van Helden 1985’s discussion is dense with misunderstandings. I regard the failure to cite here either Rawlins 1982G or Rawlins 1982H as a conscious, Mufaa-kissing misleading of the reader, by suppression of evidence against the Mufaa view propounded. I.e., the usual.

11 E.g., Swerdlow (fn 70), Neugebauer (§A1), & Van Helden faithfully following (fn 70 & §A4).

10 Numerical guesswork — even while the worthless & demonstrably (§F7) false numerological speculations of a succession of geocentrists and-or astrologers (see tables of Van Helden 1985 pp.27, 30, 32) are palpably off on the modern scholarly community as the best science available in antiquity, without even referencing dissenting literature. A8 How could such a mix of innocence and prejudice (e.g., fn 14) adorn a standard (gov’t funded) history-of-astronomy survey volume, written by historian (& sometime JHA Adv Editor) A.Van Helden? The answer is found in the ancient astronomy archcons he depended on. Van Helden 1985 p.7 indicates (see also p.168 n.16): “In the course of this project I incurred many debts. . . . A Research Fellowship from the [NEH] . . . . For the many valuable episodes of this story I have relied heavily on the researches of [Neugebauer capos] Bernard Goldstein [also sometime NEH beneficiary] and Noel Swerdlow.” (Van Helden 1985 was published by Swerdlow’s University of Chicago.)

B The Cohesive Myriad Factor

B1 Just after midnight of 1992/1/25-26, DR happened to ask himself the following question: since eq.45 of Rawlins 1991W explained “Aristarchos’ Experiment” by presuming that Aristarchos had regarded the angular-discrimination limit of man’s vision to be about

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\mu = \frac{1}{10000}\text{ of a radian}
\]

then (for null visible stellar parallax), shouldn’t his distance rs to the stars be 10000 Astronomical Units? After noting this in my diary, I consulted the “Sand-Reckoner” (Archimedes p.232) and found that it reports that Aristarchos’ universe had a limiting radius which was indeed 10000 times bigger 12 than an AU.

12 The cause of this imposition (and presumably of the who-cares-who-was-right-or-brave-or-ethical-or-original idée-fixe of the modern ancient-astronomy establishment: fn 67) is simply that the number of extant ancient texts created by competent scientists is tiny compared to the lot of superstitious pseudo-science that survives. Thus, realistic grantmanship virtually forces a coherent pretense that the latter is respectable scientific material, requiring decades of well-funded research. (See [H4; also Rawlins 1984A pp.984-986 & Rawlins 1991W fn 266.] Fortunately, some professional historians’ evidence of Ptolemy has lately been less defensive and more realistic. See esp. Alex Jones’ analyses.)

13 For the terminator to deviate more than 1/10000 of a radian from straightness, the line connecting the Moon’s horns must deviate 1/5000 of a radian from the middle of the terminator (§C4). The arcn of the ratio of this to Aristarchos’ lunar semi-diameter (1/4; eq. 3) equals 2.38’’ ≈ 3’’. (Rawlins 1991W §R9’s analyses used 0.4’ instead of 1/10000 of a radian, yielding 2.58’’ by the same equation.) Note that DR has not arbitrarily conjured-up \( \mu \approx 0.4 \) for the purposes of this paper: Rawlins 1982G (p.263, in a quite different context) noted that the mean angular separation of the retina’s foveal cones is 0.4°-0.5°. (The arcn of 0.4/15° is 3′′26’’ ≈ 3’’.) I found by experiment long ago that the eye’s primitive visual limit is about 1.7’’. (The arcn of this divided by 1/4° is 2.33’’ ≈ 3’’.) Aristarchos presumably performed just such an experiment to arrive at his value for \( \mu \). These estimates agree closely with Dawes’ limit (consistent with diﬀective Airy disk) for a human eye’s pupil-size, and all ﬂatter around \( \mu = 1/10000 \) of a radian, the value underlying (§B2) all Aristarchan celestial scales. [Note added in 2010: Was it computed from a null experiment? See www.dio.org/cot.htm#xnhx.]
B2 Thus, I realized at a stroke that all the famous Aristarchos astronomical scale measures could turn out to be consistent with the very same empirical base, namely, the limit of human vision: see fn 17.) NB: It is attested that Aristarchos investigated optical science. (Thomas 1939 & 41.2.3.)

B3 It may seem remarkable that no one previously noticed this. But such an astonishing oversight is, in fact, precisely what one would expect of the history of ancient astronomy community as now constituted, since the enterprise is primarily into detailing-repeaters the contents of ancient sources (and other safe-predictable sabbatical-length projects), and “original” research largely involves relating source A to source B — with but very occasional success in achieving the science behind either A or B. (Muffia disability here is seasoned with naked contempt for non-Muffia scholars who try.) Such work is more apt to encourage-aided-bibliographers, than to thinking scholars. (Few Muffia capos are scientists. They naïvely presume that some mathematics background will suffice to protect them from misperceiving ancient methods; but: this presumption is just one more Muffia misperception. The idea that practical experience in relating empirical data to theory might be of use in doing history of science would seem to be self-evident. Not to Muffiosi.)

C Moon & Historians in Retrograde

C1 For roughly 2 millennia, since Eratosthenes (11 fn 3) and Pappos (Rawlins 1991W fn 220), the allegedly Aristarchos work, “On the Sizes & Distances of the Sun & Moon”,

18 E.g., Van Helden 1985 p.7 on Aristarchos’ Experiment: “his method proved to be impractical. Even if he would have tried to measure his numerical data accurately, he would have found that determining the exact moment of dichotomy [half-Moon] and then measuring the angular separation of the two luminaries is a hopeless task.” Mere echo of Neugebauer’s equally indoor ignorance: fn 5.

20 Since a hallmark of the Neugebauer sales-cult is its consistent confusion of superstitious ravings (e.g., §§3A3K7) with genuine science, one can readily understand how this quiche got into the habit of quoting any old idea of attempting to relate real science to ancient texts. See, e.g., Gingerich 1976’s hyperdiagnostic-alibi-quotes defending Ptolemy (taken from Neugebauer 1975 pp.107-108), e.g., “It makes no sense to praise or condemn the ancients for the accuracy or for the errors in their numerical results. What is really admirable in ancient astronomy is its theoretical structure”. (Compare such addled archonal naiveté to the realities of §F9 & §11.) This astonishing bit of mis-megastatistics (definitively vaporized at §1 96 & fn 9) was dished up to excuse Ptolemy’s Almagest 5.14 analysis, a fudgepot so incredible that even genial centrist W.Hartner calls it a “fairy-tale” (Hartner 1980 p.26). O.Gingerich’s promotion of ON’s nationalization appeared in the American Association for the Advancement of Science’s main organ, Science. And it reflects official editorial policy at O.G’s extremely handsome Journal for the History of Astronomy (see fn 6). It would be pleasant, even if naïvely visionary, to imagine that DR might someday induce an astronomy-historian to attempt an experiment in empathy: imagining that he is the resurrected shade of a genuine ancient astronomer. In life, this scientist had spent decades [a] scrupulously testing (against observed data) various competing theories, and [b] empirically refining orbital elements & other astronomical quantities. He now returns to find 20th century archons slurring or ignoring this honest labor, instead preferring astrologers’ lazy fake-observations & other plagiarisms, maybe ripoffs of the shade’s own original genuine work. Just the sort of appreciation scientists pour out their lives for. (See fn 67 & Rawlins 1990D [B3].)

21 One among numerous instances (Neugebauer 1975 p.655 n.1): “The famous paper by Hultsch [1897] on ‘Poseidonius über die Grösse und Entfernung der Sonne’ is a collection of implausible hypotheses which are not worth discussing.” However, I urge non-Muffiosi not to emulate such arrogance and to instead appreciate that even ill-maninated bigots can make genuine contributions, which should be treated strictly on their merits.

22 There is also an implicit notion that avoiding offending archons will protect one from misadventure. Perhaps, but the level of scholarship resulting from such artificiaille has been a contributing factor in judgement-degeneration that has cursed modern history of ancient astronomy. Aristarchos: Ancient Vision 2008 March DIO 14 ¶2

has been universally accepted as genuinely his. Rawlins 1991P (fn 6) and Rawlins 1991W (1910 & fn 220) have challenged this incredible myth by exposing several internal problems of the pseudo-Aristarchos treatise. Perhaps pseudo-A’s hazy perception of Aristarchos’ astronomy is related to his resented corpus’ near-extinction by the geocentrist establishment of his day. (See below: fn 69.) If we take “Sizes” as truly being Aristarchos’, we must accept that one of the most eminent astronomers in history believed all of the following five nonsense-propositions (Heath 1913 pp.329f & 352f: Neugebauer 1975 pp.635f):

[a] The Sun & Moon are 1/15th of a zodiacal sign or 2° wide in angular diameter (nearly 4 times the correct value), thus pseudo-A’s semi-diameter was: $\theta_A = \frac{1}{15}$ / 4

(b) Lunar eclipses can last half a day (vs 4° in reality: §C8.)

[c] Mean lunar parallax is c.3°. (Actually under 1°.) So an equatorial observer would see the Moon move (nearly) its own diameter from rising to setting, a hint of [e] to come. [d] The Sun’s parallax is 9° (60 times the truth), which would cause a parallax for Venus (near inferior conjunction) of over 1°/2.

[e] In Mediterranean climes (or nearer the Equator), the upper-culmination Moon MUST BE OBSERVED MOVING IN RETROGRADE against the background of the stars. (Already noted at §1 fn 36.) Though this is an inevitable consequence of pseudo-A’s pseudo-correctness was not noticed by centuries of commentators, (e.g., Pappos (c.230 BC) & Pappos (c.320 AD) through Neugebauer 1975, Van Helden 1985, & Evans 1998. (Note the precision of the irony here in the context of ON’s arrogant attack upon P.Duhem at Neugebauer 1957 p.206, emph added: “Duhem . . . has given a description of Ptolemy’s lunar theory according to which the moon would become retrograde each month . . . . flagrant nonsense . . . . Duhem’s total ignorance of Ptolemy’s lunar theory is a good example of the rapid decline of the history of science.”) C2 However, to give credit where it’s due: the National Geographic Society has gone so far as to publish photographic proof of moonrise in the west” (Our World’s Heritage NGS 1987 pp.238-239, adorning an article by longtime Librarian of Congress Daniel Boorstin. But the photo is so ineptly faked that it provides unconvincing (not to mention irrelevant: fn 30) support for pseudo-Aristarchos’ implicitly revolutionary lunar theory.

23 The failure of prior historians, to face the outlandish absurdities of the pseudo-Aristarchos ms, is a mystery. (None has previously realized that it entailed a retrograde Moon, despite our broad hints [fn 25] on earlier inside covers.) See, e.g., Heath 1933 p.350, Neugebauer 1975 pp.634-643 (which came nearest to fully realizing the ms’ folly — but then attacked Aristarchos instead of the ms’ attribution); also Evans 1992 p.68.

24 Sand-Reckoner” p.223. With respect to the strange controversy (Rawlins 1991W fn 53) as to whether Aristarchos (also Timochares & Aristyllos) used degrees: note that the various empirical magnitudes surely connected to Aristarchos are all easy fractions or multiples of degrees: 1°/2 (solar diameter), 3° (half-Moon or quadrature), & $10°/23$ or $32°/3$ (suns remaining: Rawlins 2002A eq.6). [Note added 2011. Archimedes’ (p.224) sunwidth limits, rt.-angle fractions 1/200 to 1/164: 1°/2 = 1°/200.]

25 The “Upcoming” lists (inside-cover) of DIO 2.2 & DIO 2.3 published warnings of this bomb well over a decade ago (1992): “Hist.scient accepts, as genuine, famous ancient treatise putting Moon into retrograde!” The JHA-H.A.D. crowd never picked up on the clue. Is anyone surprised?

26 See the equally-ironic comments at DIO-JHA 1.2 fn 284. The Neugebauer 1957 p.196 passage (there compared to p.206) was first brought to DR’s attention by the late R.Newton.

27 In this handsome photo [www.doi.org/jha.html#mnrs], the Moon is seen in its rising aspect (obvious to an outdoor astronomer) low behind the camera-facing Sphinx. But the Sphinx faces eastward.
C3 Let us see how the deliciously zany retrograding consequence (§C1[eq]) comes about. Pseudo-Aristarchos’ implicit mean lunar distance (eq.5) equals 20.\textdegree.10 (where 1\textdegree = 1 Earth-radius). But it is well-known that the Moon’s sidereal period is & was 27.3\textdegree.32 (mean sidereal motion 0.\textdegree.549/hr) or 27.4 sidereal days. So an observer on the Earth’s Equator, watching the Moon (with mean distance & motion), transiting in the zenith, must therefore be travelling 27.4/20.10 = 1.36 times faster\textsuperscript{33} than the Moon, which will thus appear to be moving in reverse at about 0.\textdegree.2\textdegree/hr — the peak-speed of a (diurnal-synodic) retrograde loop (similar to the annual-synodic retrograde loops familiar to planet-watchers).\textsuperscript{34}

C4 Recall another serious problem with the pseudo-A work. We will define \(\gamma\) as the half-Moon’s angular distance from quadrature. Rawlins 1991P §C1 suggested\textsuperscript{35} that the famous Aristarchos value

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\gamma_A = 3^\circ = \arcsin(r_M/r_S) = \arcsin(1/19)
\]  

was an upper bound, not a precise figure. (The notation: \(r_M\) = the Moon’s distance, and \(r_S\) = the Sun’s distance.) Even allowing this,\textsuperscript{32} Rawlins 1991W fn 272 showed that as merely

\textsuperscript{32}Heath 1913 p.339 & Neugebauer 1975 p.637 perform the same math, understandably with less precision.

\textsuperscript{33}The pseudo-Aristarchos Moon, at mean geocentric distance 20.\textdegree.10, will travel 20.1 times farther per Earth-circuit than will an observer on the terrestrial Equator. But this circuit will take 27.4 times longer to perform. Thus, as noted above, the mean geocentric speed of the equatorial observer must be 27.4/20.1 = 1.36 times greater. When the Moon is in the equatorial observer’s zenith, he is only 19\textdegree.1 distance from pseudo-A’s Moon, so the Moon’s relative hourly angular “topocentric” or observer-centered motion is (20.10 – 27.4/20.10 – 1) times the mean geocentric sidereal hourly lunar motion (0.\textdegree.549) or: -0.2. (Obliquity’s cos = 92%, ignorable for rough mean-situations: [a] when the Moon is off the Equator, its motion is parallel to the terrestrial observer’s, [b] when the Moon’s geocentric motion is parallel to the Equator, the Moon is not on the Equator.)

\textsuperscript{34}Maximum apparent retro-motion would always occur around lunar transit (which is one reason why §C2 calls National Geographic’s faked rising-Moon photo irrelevant to the present discussion), analogously to an outer planet’s motion near opposition. This entire effect may sound as if it is purely theoretical, whereas there is in fact a readily-discernable slowdown of topocentric lunar angular speed when the actual (not ancient-theoretical) Moon is high. I.e., there is a retrograde tendency, due to the Earth’s spin; but in reality this superposed parallactic motion’s speed is — due to the Moon being about 60\textdegree (not 20\textdegree) away from the Earth’s center — not fast enough to overcome the Moon’s sidereal motion.

For the real overhead equatorial Moon at mean distance & mean sidereal speed, the equatorial observer will be traveling only 27.460.27 times the Moon’s sidereal speed, so the Moon’s absolute topocentric 0.\textdegree.56/hr speed is slowed to a relative angular speed of about 0.\textdegree.3/hr. (When the Moon is near the equatorial nadir, this relative speed would be seen — if it were visible — to be 0\textdegree.8/hr. Over time, the speed must of course average out to the mean lunar geocentric sidereal speed: 0.\textdegree.549/hr.) This generally-neglected effect (which I have frequently observed firsthand — and without optical aid — during temperate-latitude high Moon-star appulses) could easily have been measured by the ancients, to yield a useful estimate (§C11) of the Moon’s distance \(r_M\). Yet another reason for the incredibility of the wildly false values for \(r_M\) entailed by pseudo-Aristarchos. Without, that is, both the emendations here suggested (in \(\theta\) & \(v\)), which lead to the reasonable values found in eq. 11.

\textsuperscript{35}A weird variant of DR’s upper-bound approach (to explaining Aristarchos’ 3\textdegree) appears in Evans 1998 p.72. (With no citation of Rawlins 1991P.) Though Evans speaks of “least perceptible” inequality in crescent and gibbous portions of the month (without asking how the \(\gamma_A = 3^\circ\) boundary between these portions is determined! — a difficulty which throws us right back into the mire of the very problem allegedly being solved), he says Aristarchos “simply made up the value” — faithfully converting a physical argument (“perception”) into the orthodox Neugebauerism cited above at §A1.

As early as Archimedes (p.223), Aristarchos was cited as claiming that the Sun/Moon distance ratio is between 18 & 20 (prop.7). At first glance, it seems that this bracket reflects data-precision. Hardly. [a] The range indicated is purely mathematical (not empirical). (See Heath 1913 pp.376-381. The math is a geometric approach to a problem more accurately done by either simple circle-math [like that of [SC5] or by trig, which could suggest that trig did not yet exist c.280 BC. For contrary evidence c.275 BC, see Rawlins 1985G p.261 & fn 9. The two evidences together may indicate

an upper bound, said 3\textdegree figure depends upon visual discernment of ordmag 1/10000 of a radian — c.1\textdegree/3, very near the limit of human ocular discernment. (I am of course taking it for granted that the fineness of human vision has not changed significantly since 280 BC.)

C5 We have seen earlier from Eusebius ([\(\theta\)l 14.9) that Eratosthenes placed the Moon at a distance of 19 Earth-radii, at a figure presumably gotten from pseudo-Aristarchos. (Unless universe-shrinking Eratosthenes was himself pseudo-A. The document’s curiosities [e.g., [\(\theta\)l fn 4] cannot be traced back beyond Eratosthenes).\textsuperscript{36} And this is the figure computed from pseudo-A’s propositions 11&17 at Heath 1913 pp.338-339. Yet Heath bases this on averaging depressingly crude brackets associated with needlessly pedestrian geometric proofs. By contrast, an exact computation (e.g., Neugebauer 1975 p.637) finds 20 Earth-radii instead of 19:

\[
\tau_M = \frac{1 + \sin \gamma_A}{(1 + v_p) \sin \theta_P} \approx 20^\circ.10
\]  

using pseudo-A’s false data (§C8 & eq.2): shadow-Moon ratio \(v_p = 2\) and solar semi-diameter \(\theta_P = 1^\circ\). Question: if you wished to find 1/sin \(\gamma\) or (virtually the same) the distance/size ratio for something subtending \(\gamma\), wouldn’t you just figure that the circumference is \(2\pi\) times the distance and \(1^\circ\) is 1/360 of that, so distance/semi-diameter \(= 360/2\pi = 57.3^\circ\)? (The pseudo-A brackets instead can only put the number somewhere between 45 & 60! It’s hard to accept that Aristarchos was this limited.) Is there a more reasonable explanation for why a very simple computation which should have produced 20 instead got 19? [Our next speculation parallels known Hipparchan researches: Alm 5.11.]

Try this: since \(DIO\) has for years pointed out (§C4) that \(\gamma = 3^\circ\) is probably an upper bound (not an exact figure), why not explore the obvious consequence of this assumption, namely, that (not knowing where \(\gamma\) was in the range \(0^\circ\) to \(3^\circ\)) simply made it null for solar distance \(r_S \approx \infty (\gamma = 0^\circ)\). In that case, eq.5 becomes:

\[
\tau_M = \frac{1 + \sin \theta_P}{(1 + v_p) \sin \theta_P} \approx 15^\circ.100
\]  

(More efficiently: \(\tau_M \approx 60^\circ/191.9\).) So, Eusebius’ verification that a lunar distance of 19\textdegree was an accepted figure turns out to lend potential if as-yet-speculative support to the common-sense \(DIO\) theory that eq.4’s \(\gamma = 3^\circ\) was indeed (§C4) an upper bound for Aristarchos, showing his openness to the possibility that the universe was many times larger than that implied by taking the 3\textdegree figure as exact.

\textsuperscript{36}Has it been previously noted that Aristarchos’ near-contemporary Archimedes (probably a few years older and light-years brighter than Eratosthenes) reports none of the follies of pseudo-Aristarchos? (Which perhaps sandwiches the time of pseudo-A’s origin into the 2\textsuperscript{nd} half of the 3\textsuperscript{rd} century BC.) The nearest he comes is in referring to Aristarchos’ Sun/Moon distance-ratio as being between 18&20, a mere confusion (identified elsewhere: fn 32) of geometric method with precision. But Archimedes doesn’t repeat any of the key giveaway screwups of pseudo-Aristarchos: 2\textdegree-wide Sun (indeed, he contradicts it), lunar distance 19\textdegree, Earth-shadow/Moon ratio = 2. Note also the clash between Archimedes-Aristarchos (eq.15) and pseudo-Aristarchos (Heath 1913 pp.339 & 350) on \(rs\): 10000\textdegree vs 360\textdegree, respectively. Were Aristarchos’ works more welcome in Archimedes’ Syracuse than in Eratosthenes’ Alexandria (by then of less-Greek rulership, and scantly strained from funding wars, e.g., Pyrrh’s)? See §1 §F3. (What Alexandria instrumental star data survive from the 100\textdegree after Aristylos, 260 BC?)
In addition to the flock of pseudo-A difficulties cited above (§C1 & fn 32), Rawlins 1991W §R10 also revealed a hitherto-unnoticed internal contradiction in the pseudo-A work: the explicit (and false) statement that 1/3960 of a rt angle is too small to be visually discerned (Heath 1913 p.370, Neugebauer 1975 p.640). However, 1/3960 of a rt angle is 4 times bigger than 1/10000 of a radian. So, this pseudo-A statement wipes out the entire visual basis (fn 17) of Aristarchos’ Experiment!

C7 The foregoing shows (in overkill proportions) that the pseudo-A treatise is not to be accepted as the output of a competent astronomer. One may assume either: [a] Aristarchos was a fool (fn 34), or [b] the show is not by him. I prefer option [b]. However, more important than the author’s identity,34 is the astronomy behind pseudo-A.

C8 Having thus already (§C1[a]: “μπορεί”) cleared up pseudo-Aristarchos’s most obvious absurdity (eq.2: 1° lunisolar semi-diam $\theta_P$), we check another highly suspect pseudo-A statement, namely, that, at the Moon’s distance, the pseudo-Aristarchos ratio $v_P$ of the Earth’s umbra (shadow-width) to the lunar angular-diameter is just 2. (Computing with accurate $v$ is crucial for finding the lunar distance: eq.11.) But this $v$ would (eq.10) cause central eclipses’ Entirety (Partiality + Totality) to be 3 times longer than Totality. Letting $\rho$ stand for the Entirety/Totality ratio, we have pseudo-A’s $\rho_P = 3$ (eq.10). But it is well known that an eclipse’s maximum possible Entirety is instead just under $4^2$, while maximum Possible Totality is slightly more than $1^2$ — that is, roughly $\rho = 2$ — creating an Ent/Tot ratio $\rho$ of barely 2 (far short of Ent/Tot = 3). For the mean distance situation, the actual shadow/Moon ratio $v$ is 2.7 (corresponding to Ent/Tot ratio $\rho = 2$ 1/6; fn 35). And we know that Hipparchos used $v = 2.5$ (Almajest 4.9), while Ptolemy used $v = 2.6$ (Almajest 5.14). So, how could an observing astronomer set $v = 2.7$? The basis for estimating $v$ is eclipse records. (And Aristarchos may have researched and drawn wisdom from such records much as any other Greek of his day: DIO 11.1.1.) The simplest method would be to use central eclipses (Earth-shadow & Moon concentric at mid-eclipse): those for which the lunar path virtually bisects the shadow. By averaging a few empirical distance data from such central events, one may (eq.7) compute $v$ from the ratio $\rho$ of the time of an Entire umbral eclipse to time of Totality (for central eclipses), which is (crudely) $4^2/2^2 \approx 2$, a figure that reveals (via eq.7) $v$ to be much nearer 3 than 2. Even aside from Aristarchos’ access to centuries of Babylonian eclipse records, he could have observed first-hand the 21-digit eclipse of −286/5/20 (ρ = 2 1/5); and-or the 19-digit eclipse of −279/6/30 (ρ = 2 1/4), which occurred just a few days after his famous S.Solstice observation. Such easy observations would make it clear that $v$ was nowhere near 2. One possible cause of pseudo-A’s wacky $v = 2$ is unhelpful confusion: pseudo-A carelessly took $\rho$ (something about in-shadow, wasn’t it...?) to be $v$. (We already know from §§A1&C1 how easily confused pseudo-A was.) Keep in mind: the Entire/Totality ratio $\rho$ is an easy raw-empirical number, while $v$ is derivative. Another possible explanation of the pseudo-Aristarchos $v$-vs-$p$ foulup arises quite naturally from an examination of the near-inter-relationship between $\rho$ and $p$:

$$ v = \frac{\rho + 1}{\rho - 1} \quad \rho = \frac{v + 1}{v - 1} $$

(7)

C9 Eq. 7 is a special case (where constant $a = 1$) of what I’ll call the “Reversible Fractional Function” (RFF):

$$ y = R(x) = (x + a)/(x - 1) $$

(8)

34 It is possible that pseudo-A was an uninformed hyperentepid (as Neugebauer 1975 p.643 speaks of Aristarchos, believing him to be the author of “Sizes”) — as politically powerful as he was incompetent. Poseidonio is also connected (Neugebauer 1975 pp.654) to $v = 2$, perhaps while assuming cylindrical shadow (which ON naively relates to null parallax). Did $\rho = 2$ evolve from such mis-megistry? Alternate route: if a key pseudo-A slip miscontrad $R$/$\rho$M = 19 (eq.4) as $R$/$\rho$M = 19 (eq.6), then eq.6 could have produced $v = 2$. (Less likely: eq.10 and $\rho$M = 19° into eq.6) caused $\theta_P = 1°$.

It is not immediately obvious that the deceptively simple expression $R(x)$ brings out the fun in function — by the following cute property:

If $y = R(x)$, then $x = R(y)$.

C10 Had the real Aristarchos genuinely believed $v = 2$, he must have realized that this correlated (again via eq. 7) to $\rho = 3$ — which was plainly false, as anyone of the slightest experience with eclipse records would know. But we recall (§C8) that actual $\rho$ just 35-exceeds 2, and no lunar eclipse datum is easier to find. Thus, it is not credible that Aristarchos would opt for $p = 3$ — a value nearly five times as far from the truth as that which I will here suggest was actually his original, namely, a rounding of the crude $\rho = 4^2/3^2$ ratio noted in §C8 as too plain to miss, that is: $\rho_A = 2$. And this entails (via eq.7) a comparably better value for the shadow-moon ratio $v_A$, so we can be pretty sure Aristarchos used:

$$ \rho_A = 2 \quad v_A = 3 $$

(9)

Note that, if we accept pseudo-Aristarchos, eq.9’s roughly valid values became reversed into ridiculous falsity:

$$ v_A = 2 \quad \rho_A = 3 $$

(10)

Thus, in brief, inspired by our §C1 revelations of pseudo-A’s unreliability, I am suggesting (§C8-C10) that pseudo-A, through sloppiness or ensnarement by symmetry (of the eq. 8 RFFunction), either:

[a] misunderstood a reference to $\rho$ (commonly known to be about 2) as a reference to $v$, or

[b] simply confused Aristarchos’ $\rho_A = 2$ & $v_A = 3$ with each other! (Easy mix-up for an amateur, since, as eqs. 7&9-10 have revealed: when either of the two variables equals 3, the other equals 2. Note also cylindrical-shadow confusion at fn 34.) Let us now explore the consequences of this simple (though speculative) hypothesis.

C11 We substitute eqs. 3 & 9 into the usual eclipse diagram equation36 (e.g., eq.5) and thus obtain:

$$ r_M = \frac{1 + \sin \gamma_A}{(1 + v_A) \sin \theta_P} \approx 60^\circ or 51^e $$

(11)

for $\gamma_A = 3^\circ$ (eq.4) or $\gamma_A = 0^\circ$ (eq.6), respectively. Both $r_M$ are correct within c.5%. (Moon’s actual mean distance: 60°. It should be kept in mind that $r_M \approx 60^\circ$ might already have been independently realized [roughly] by measuring: [a] the slowing of the Moon’s motion near transit, as described here at fn 30; or, [b] rising-vs-setting parallax, as hinted at in §C1 [c].) It is by no means improbable that $r_M$ known to within a few Earth-radii in 280 BC — after all, it depends critically (in eq. 11) only upon $v$ (or $\rho$) and $\theta$; and both of these are easy to find accurately enough for that purpose. (Keep in mind that Aristarchos knew the Moon’s period to a precision that certainly doesn’t sound like a mere “theoretical” math-pedant: [F9] vs. §A1, fn 20, & fn 34.) In fact, the idea that Aristarchos was so ignorant as to mistake $r_M$ by a factor of roughly 3 (20%: §C3 & eq.5) — or even a factor as large as 4/3 (80%: Rawlins 1991W eq.31) — is difficult to countenance, since these blunders would require almost impossibly large errors in $\rho$ and (especially) $\theta$.

D Solar System Scale

D1 We next find what the foregoing implies for solar distance $r_S$. From eqs. 4 & 11:

$$ r_S = r_M/\sin \gamma_A \approx 60^\circ / \sin 3^\circ \approx 1146^e \approx 1000^e $$

(12)

35 In reality, mean $\rho \approx 2$ 1/6, as one will find from a glance through an eclipse canon or by substituting $v = 2.7$ (§C8) into eq. 7.

36 Almajest 5.15 or Rawlins 1991W eq.27. This equation depends upon setting the solar & lunar semi-diameters equal to a common $\theta$. 

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(The obvious large uncertainty in γ justifies rounding $37 \ 1146' = 1000'$.) Such a step could have triggered the later tradition — discovered by Hipparchan eqs.23&24 of Rawlins 1991W — of dividing $38 \ 1$ AU into units of thousandths: 1 AU = 1000'.

D2 About 900 AD, Al-Battani’s solar work, explicitly building upon the remains of Greek solar theory, exhibited precisely $r_s = 1146'$ (and failed to supply coherent justification for the choice: fn 39). This suggests (though it hardly proves) $39 \ 1146'$ had become a standard value in some Greek traditions.

D3 Previous attempts to deduce Aristarchos’ $r_s$ (from eq. 11) led to values such as 384' (Heath 1913 p.339 or Neugebauer 1975 p.637 eq.20, calculating exactly) and, quadruple that, 1536' (Rawlins 1991W [§Q5]). (The first value was based on unaltered pseudo-Aristarchos; the Rawlins 1991W value was based upon only 1 of the 2 emendations to pseudo-A (namely eq. 3). However, neither of these 2 values is directly attested. Thus, given Al-Battani’s use (§D2) of 1146' (eq. 12), we may conclude that: [a] the value 1146' is the preferred choice (of those discussed here) for Aristarchos’ early $r_s$ (see also fn 37), thus [b] our 2 emendations (eqs. 3&9) are not-disconfirmed.

E Aristarchos & the Sea goat: Expanding the Universe a Trillion Times

E1 The irony is that Aristarchos’ famous Experiment was far inferior to his greatest heliocentric scale-contribution. As remarked here at §B1, Aristarchos thought out the implications of heliocentricity to their astonishing and historic conclusion: the absence of naked-eye-visible stellar parallax showed that the stars were at vastly greater distances than geocentristians had realized.

$37 \ \text{The hypothetical rounding of } r_s = 1146' \text{ (to } 1000') \text{ would produce a slight inconsistency in eq. 12, but } r_s = 60' \text{ would yet imply } r_s = 3^\circ 26' \approx 3'. \text{ Note that } 1146' \text{ is much nearer } 1000' \text{ than any previous scholar’s estimate of Aristarchos’ value for } r_s; \text{ §D3. From fn 18 or eq. 13, we see that Aristarchos ultimately may have ordmed-ranged } r_s/k = 1000. \text{ In any case, Rawlins 1991W eqs.23&24 prove that he (at least initially) and-or later followers rounded } 1146' \text{ to the nearest } 1000', \text{ or divided the } AU \text{ into a thousand million: } AU = 1000'. \text{ Whether or not these ancients’ micro-measure was Earth-radii, the 1991 analysis shows that their macro-measure was heliocentrically AU-based.}

$38 \ \text{Whatever its origin, this standardization does not imply consistent perpetuation of } 1^\circ \text{ with } 1', \text{ though such an equation may well have had at least passing popularity. It seems that, during the } 3^\text{rd} \text{ century BC, } r_s \text{ was initially (from Aristarchos’ Experiment) set at ordmag } 1000'; \text{ and then later (due to failure to observe planetary diurnal parallax, as noted here at §F), heliocentrist astronomers (contra geocentrists: §F5) enhanced } r_s \text{ an ordmag, up to } 1000' \text{ — the same Archimedean myriad ratio also adopted for } r_s/r_g \text{ at eqs. 13 & 14.}

$39 \ \text{It is always possible that the values broached above (} r_M = 60' \text{ and } r_s = 1146' \text{) actually came from a completely different source than here suggested. Swerdlow 1969 has a persuasive argument that Hipparchos’ } r_s = 490' \text{ was based on an adopted solar parallax of the rounded value } 7'. \text{ Similarly, if an ancient had adopted a rounded solar parallax of } 3', \text{ he would (as independently noted at Van Helden 1985 p.31) deduce } r_s = 180' \times 60'/3' \pi = 1146' \text{ (a figure later used by Al-Battani: §D2 & fn 57) — and he could then, from a rearranged version of eq. 12, arrive (backwardly & shakily) at } r_M = 60'. \text{ On the other hand, it might be that, if Hipparchos concluded for } r_s \approx 490' \text{ (Swerdlow 1969), he did so (as he did so much else, e.g., Rawlins 2002A fn 14, 16, & 17) following Aristarchos’ lead, which in this case would probably mean building upon } \gamma \text{ rather than solar parallax. If he adopted } r_M = 60' \text{ from Aristarchos (eq. 11), and believed he had measured } \gamma \text{ to } 7', \text{ then he would revise eq. 12 into: } r_M = 60'/7' = 490'. \text{ Or, if Hipparchos in-} \text{dependently stuck by an early value } [\text{Rawlins 1991W §R1} r_M = 77' [\text{itself based on } \gamma = 3'] \text{ and then shifted to } \gamma = 9'; \text{ he might have in-} \text{correctly computed } r_s = 77'/\sin 9' = 492' \approx 490'. \text{ For Hipparchos’ } r_s = 77', \text{ see, e.g., Swerdlow 1969 p.289.}] \text{ Van Helden 1985 p.167 n.8 supplies similar speculations.}

$40 \ \text{The intimate relation of Aristarchos’ Experiment to heliocentricity is seldom mentioned in modern textbooks (perhaps due to the ironic geocentric-preference noted at fn 72), though obvious from the Experiment’s large implied solar volume: Rawlins 1991P §C3. That the Experiment & heliocentricity are due to the same scientist is thus implicitly regarded as merely a coincidence!}

E2 How much greater? Well, according to Archimedes (d. 212 BC), the previous & still-current definition of “universe” was such that its radius was 1 AU. Aristarchos realized that, since the Earth (not the Sun) was moving in a circle of this radius, then: the invisibility of stellar parallax demanded that $r_s$, the closest stars’ rough mean distance (in AU, where $r_s \equiv 1$ AU), be as great or greater than the inverse of the limit of human vision (in radians). From “Aristarchos’ Experiment”, we have already shown independently (§B1) that he used 1/1000 of a radian for that limit. Thus, from eq. 1, we would have set $r_s = r_\mu/k = 10000 \cdot r_s = 10000 \text{ AU}

(13)

So it is gratifying to find this result is actually testified to (§B1) as a limiting distance by Archimedes’ “Sand-Reckoner”. $31 \text{ But such a scale, though (§E1) much more important than the famous “Aristarchos Experiment”, is far less known today. Exceptions are Heath 1913 (p.348) & Neugebauer 1975 (pp.646&656). But, following the usual misconception that Greeks were non-empirical, neither author considers the possibility suggested here (eqs. 1&13), namely, that this figure was founded upon systematic scientific observations.}

E3 Yet it is not difficult to reconstruct the empirical basis. Aëtios (a late source) appears to indicate that Aristarchos regarded the stars as suns, $42 \text{ saying (Heath 1913 p.305) that he “sets the sun among the fixed stars and holds that the earth moves around the [ecliptic]”. Aristarchos would probably regard stars’ distances as being as randomly varied as their brightnesses.}

E4 Thus, the simplest experiment for measuring stellar parallax would be that which was later vainly attempted by W.Herschel (during the project which led him instead to his historic accidental backyard 1781/3/13 discovery of Uranus): look for annual oscillation in the relative positions of false double stars (i.e., two stars which happen quite by chance to be so situated that a line through them passes very nearly through the Solar System), where one of the stars is much nearer the Sun than the other. Some good examples: Giedi, Mizar-Alcor, and Shaula-Lesath. Giedi (the east horn of the SeaGoat, Capricorn) is probably the best example. In the time of Hipparchos, the separation between the Giedi pair ($\alpha$ & $\beta$ Cap, respectively) was merely 5 arcmin: $3'.7$ in longitude, $3'.3$ in latitude. $43 \text{ The searched-for parallactic motion would be almost entirely in longitude. Yet it is certain that no such relative motion was ever observed. An ancient might aibi this by supposing that Giedi’s 2 stars were of similar distance; however, repeated experiments all over the sky would give the same result. Which meant that annual parallax was invisible either from: [i] all stars being at the same distance or [ii] stars’ remoteness & thus invisible parallax. The former option would probably be rejected: if the seven “planets” were all at different distances, why should thousands of stars all be at only one distance?}$42

$45 \text{ If Giedi’s nearer star (}\alpha\text{ Cap}$)
were, say, 1000 AU distant and $\alpha$ Cap much more remote, then, the 2 stars' relative positions in April vs. October would correspond to baseline 2 AU (see fn 18) — and thus: a total ecliptical parallactic swing of about 2.4$^{\circ}$ — and thus: a total ecliptical parallactic swing of about 2.4$^{\circ}$, which implies a total ecliptical parallactic swing of about 2.4$^{\circ}$ for the latter case by his analogy that stars' huge distances render Earth's orbit punctal by comparison. Note: eq.14 is based on Aristarchos' denial of the visibility of both solar & stellar parallax, expressed for the latter case by his analogy that stars' huge distances render Earth's orbit punctal by comparison.  

Heath 1913 p.348 supposes that the 10000$^{\circ}$ figure (for which no sensible Poseidonios evidence survives) is based on Archimedes' "Sand-Rectoner" exercise. But this speculation was lodged before 1/10000 of a radian was found (§C4 or Rawlins 1991W fn 272) to underlie Aristarchos' Experiment — with the attached suggestion that it was ancient scientists' recognized $\alpha$ (eq. 1). The further suggestion is that Archimedes' allegedly pure-math exercise actually reflects prevailing heliocentric opinion, in

As Heath notes, this is in the right ballpark (only off by a factor of about 2). It implies a solar volume of ordmag 100,000 Earths! Given the sheer solar mass obviously indicated, this would suggest (Rawlins 1991P §C3) to anyone outside the Muffia that Poseidonios was teaching a heliocentric conception of the universe — as also did Seleukos. (Heath 1913 p.305 cites several of the ancient testimonies on heliocentrist.) And Poseidonios also suggested that the stars can match or even exceed the Sun in size (Neugebauer 1975 p.965).

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**F1** There is a hint (Archimedes p.222, Neugebauer 1975 p.646 eq.11) that Aristarchos, ultimately promoted a provocative distance-limit-symmetry ($r_T = \text{Earth radius}$): $r_2/r_5 = r_5/r_T = 10000$ (14)

This would, if true, represent an abandonment of eq. 12. Regardless of our speculations as to whether Aristarchos himself shifted from eq. 12 to eq. 14 (Archimedes suggests otherwise), we know (§F2 & eq. 14) that astronomers did so shortly thereafter.

**F2** Kleomedes 2.1 reports (Heath 1913 p.348, Neugebauer p.656, I.Kidd 1988 p.445) that Poseidonios (1$^{\text{st}}$ century BC) considered the possibility that the Sun was (at least: fn 18) 10000$^{\circ}$ distant. This is already given in eq. 14, namely:

$$r_5 = 10000$$

(15)

**F3** What can have caused the shift in heliocentrist's adopted $r_5$ from 1146$^{\circ}$ (ordmag 1000') to 10000? The answer is obvious the moment one has recourse to observation, which (if $r_5$ is assumed equal to c.1000) produces a reduction to empirical contradiction, similar to that found via Giedi (§E4 null-parallax) or stellar distance of 1000 AU (§E5).

**F4** It is a striking fact that all 3 extant reported ancient planet-star occultations are Hellenistic and are not long after Aristarchos' time. One is by his contemporary Timocharis (Almajest 10.4): Venus in $-271$. The other two are of Mars (Almajest 10.9) the same year, and of Jupiter (Almajest 11.3) in $-240$; both are recorded according to the Dionysios calendar. (DIO 1.1 §23 identified Dionysios for the first time, and uncovered evidence of the very heliocentrist connection [to Dionysios] long suspected by DR & van der Waerden. See van der Waerden 1984-5 p.130.)

**F5** From §F4, we conclude: it is not a wild speculation to suppose that Aristarchos were examining planet-star occultations — which just happen to have been the best hope for ancienters' gauging $r_5$ in Earth radii. In a moment, we will show (§F6) how such observations will swiftly eliminate Aristarchos' initial idea that $r_5$ = 1146$^{\circ}$ (eq. 12). After this value was rendered obsolete, it evidently lingered on anyway among psychologically-receptive geocentrist, e.g., Al-Battani. He, like Hipparchos & Ptolemy, preferred $r_5$ to be as small as possible so the Sun wouldn't be so embarrassingly bigger than the tiny alleged terrestrial Central of the Universe. (And Eratosthenes had the universe even sniggle: ? §F3.) Interestingly, this geocentrist tradition misled the first modern public heliocentrist, Copernicus, who set $r_5 = 1142^{\circ}$, close to Aristarchos' initial 1146$^{\circ}$ value (& not far from Ptolemy's). Later, public-heliconist Tycho used 1150$^{\circ}$ (Thoren 1990 pp.302-304). So: [a] Aristarchos' Experiment was the basis of Solar System scales for nearly 2 millennia, adopted (at least) by Ptolemy, Battani, Copernicus, Tycho, successively. [b] Poseidonios' $r_5 = 10000^{\circ}$ (eq. 14), was in accuracy, superior to all those later figures.
F6  We will next show that the superiority of Poseidonios’ conception was probably based on observation, not “naïve” guesswork (Neugebauer 1975 pp.655-656). For solar distance $1146^\circ$ (eq. 12), the Sun’s diurnal parallax is $3^\circ$. Now, when Mars reaches a station and is roughly near perihelion, it can be less than $0.5$ AU from the Earth — which means that a $3^\circ$ solar parallax corresponds to about $6'$ of Mars parallax. At Alexandria’s latitude, $31^\circ$N, while Mars is visible during the night, an observer will be transported well over $1$ Earth radius (transversely to the Earth-Mars vector) by the Earth’s axial rotation. So, for $r_2 = 1146$, Mars ought to show ordmag $10^\circ$ of diurnal parallactic shift in one night — an angle easily detectable by eye (comparable to the lunar semi-diameter). Meanwhile (as could have been noted by a transit observer like Timocles), Mars’ apparent geocentric longitude will vary by merely about half an arcmin over the $48^\circ$ period around the station ($1^\circ$ beforehand). Such stations must have frequently occurred near enough to stars that the invisibility of the predicted parallactic shift was repeatedly verified.

F7  There is another planet-star method which requires (not the neat timing of hitting on a station but) a wide geographical range of observations. When Venus is near inferior conjunction, it can be less than $0.3$ AU from the Earth. (About $1/3$ of an AU at stations.) I.e., Venus’ diurnal parallax$^{58}$ can be more than triple the Sun’s. But for $3^\circ$ solar parallax ($\text{eq. 6}$), Venus’ greatest diurnal parallax$^{46}$ should be as high as about $10^\circ$. If Venus passed near a star, then one need only compare observations taken, say, at Meroë (latitude $L = 17^\circ$), vs. ones taken, say, at Byzantium ($L = 41^\circ$). The north-south angular distance between planet & star at conjunction should differ by about $5^\circ$ — simply detected by the naked eye.

F8  I propose that our fragmentary record ($\text{eq. 4}$) of ancient planet-star occultations is part of Aristarchos’ systematic empirical$^{47}$ testing — which eventually converted heliocentists, c.270 BC (sometime between Aristarchos’ Experiment & the Callippic period). From $1146^\circ$ (eq. 12) to $r_2 = 10000^\circ$ (eq. 15). (Such observations, in proving solar remoteness, also proved solar hugeness and thus supported heliocentricity: $\text{eq. 2}$ & Rawlins 1991P (C3.)

F9  Summing up the evident situation: we have examined all 3 of the surviving astronomical scales connectable to ancient heliocentists (eqs. 4, 15, & 13); and we have found that each of the 3 is founded on exactly the same empirical base: eq. 1, namely, the correct assumption that the limit of human vision is about $\mu = 1/10000$ of a radian. This present coincidence lends more credibility to the empirical-base theory proposed here, than most current astronomy-historian archons will ever admit. However, these archons’ own standard myth of the Greeks as mere navel-contemplating theorists has here been revealed as just that: a myth — based upon (implicitly) treating surviving documentation of ancient work as a representative sample. And the slightest common-sense consideration of the long process of filtration of ancient materials (before they reached us) will warn a freshman historian against such naïvete. (Which is spoofed at DIO 2.1 §1 §3). See also DIO 9.1 §3 fn. 8.) Since I expect the old view to persist regardless, I merely urge loyalists to offer a coherent explanation explaining how allegedly indoor Greek “theorists” came into possession of the sidereal year and the periods of the Moon (synodic, anomalistic, draconitic), Mars (probably Venus) which are accurate to 1 part in ordmag a million or better. (See Rawlins

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58 Venus has higher diurnal parallax than Mars, but the method fails for Venus since it rises/sets so soon after/after Sun’s rise/set when stationary. By contrast, stationary Mars stays up most of the night.

59 Almagest 9.1 taught that planetary diurnal parallax was invisible. (See Rawlins 1991P §3.F.) But Swerdlow 1968 correctly notes (p.102) that planetary diurnal parallax “is too large to be ignored” (ordmag $1^\circ$ for Mercury, in Ptolemy’s system) — even though Ptolemy continued to insist (p.103) that such parallax cannot be measured! Ptolemy later admitted (PlanHyp 1.2, B. Goldstein 1967 p.9) that Mercury, Venus, & Mars must show some diurnal parallax, according to his solar distance; but he does not claim he ever observed such — or even tried to.

60 Harter 1980 p.12 points out that, by Ptolemy’s scheme, even larger diurnal parallaxes should be exhibited by Venus & especially Mercury. See fn 59.

61 Ptolemy eventually acknowledged that nontrivial diurnal planetary parallax was implied by his system. See fn 59, and the useful discussion & distinction at Taub 1993 p.167.

G The Force of Reason and the Force of Prison

G1  We recall O’Gingerich’s suggestion ($\text{eq. 2}$) that Aristarchos’ contributions were neither nor off-the-top-of-the-head. Thus, Aristarchos’ demotion may be rationalized in the same fashion as the Mufa’s downgrading of the works of creative moderns of whom it disapproves. Gingerich 1985A p.(41): “For better or worse, scientific credit goes generally not so much for the originality of the concept as for the persuasiveness$^{60}$ of the arguments. Thus, Aristarchus will undoubtedly continue to be remembered as ‘The Copernicus of Antiquity’, rather than Copernicus as ‘The Aristarchus of the Renaissance’.”

G2  The most obvious problems with these typically anti-revolutionary OG comments (on 2 brave revolutionaries):

[a] To suggest that we slight Aristarchos, merely because attacks on his heresy and on his intellectual freedom$^{63}$ succeeded in virtually burying his work — despite his high ancient reputation (Rawlins 1991W §Q1) & achievements$^{64}$ — is effectively to endorse dictatorial bullying & idea-imprisonment. I cannot begin to imagine why the Mufa would sympathize with and effectively endorse such behavior.

[b] Must we follow Neugebauer&OG in letting the brilliance, boldness, & vindication$^{65}$ of Aristarchos be lost in the celeb-spotlight both men shine instead on astrologer-quackery?

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60 The values for the sidereal year and the synodic month — generally known as the “System B Babylonian month” — are good to about 2 parts in ten million, and DR has traced both to Aristarchos (Rawlins 1991H fn 1, Rawlins 1999, Rawlins 2002A). The earliest cuneiform record of the ‘Babylonian’ month is decades after Aristarchos.

61 See also Gingerich 1986 & (even valuable Gräflich 1990’s pp.215-216), excusing Ptolemy’s fudgings to agree with predecessors’ theories. Should a field’s leaders become automatic prominent apologists for the most notorious intellectual thief in the history of astronomy?

62 See similar excusing of discovery-misattribution in OG’s JHA 11.2:145; 1980/6 (statement by Lord H & OG). One senses just how usp the JHA Edition gets at plagiarism.


64 Besides the present findings, see e.g., Rawlins 1991P fn 1 and Rawlins 1991W §N7 & eqs.22-24.

65 If we were asked to point to the single feature that most clearly separates scientists from centrist historians in this area of scholarship, it would be this: history of astronomy has become (fn 6, 20, & 64) so knee-jerk anti-judgemental regarding its subjects (though not its turf-competitors) that it has lost the fact that vindication-by-future-experimentation is not anachronistically mis-history but rather is: [i] what scientists dream of, & [ii] the standard test of scientific theories’ truth or falsity. To trace how hist.astronom scholars have even so divorced from these realities (of the very field they purport to chronicle) is a job I recommend for an enterprising young archaeologist of strong stomach & dysfunctional nose. (Is it coincidental that Hist.sci was the womb from which the “paradigm” alibi for inferior science was born? Whether symptom or cause: an unfortunate backward step for modern Hist.sci may have been its archon T.Kuhn’s launching of the buzzword “paradigm”. When I was involved in anti-occultist efforts years back, I found that, while virtually no productive scientists have any use for the word “paradigm”, it was a fave with explo staff who longed to obscure and ably the failures & fakerys of astrologers & other pseudosciemens.)
H Heroes & Zeros

H1 Since most great work is the tip of a pyramidal anonyimceberg, it is risky (and usually unjust) to single out one figure as The Greatest, in any field. However — despite Cleanthes’ worst efforts at grounding him — Aristarchos’ winged mentality soared beyond his terrestrial confines of physical gravity and academic bigotry. And he still glimmers, through the haze of our indistinct record, as the ancient astronomer who perceived, proved, and published the realization that the universe’s volume is a trillion (10^{12}) times larger than hitherto understood, which reveals him to have done even more for our spatial perspective than what 19th century geology & biology did for our temporal vision. His

69 DIO 1.1 §15 fn 24, 16 [HT, 77 §82.

60 See fn 65. Heath 1913 p.304 (also DIO 1.1 §13) recounts Cleanthes’ attempt (paralleling later threats against Galileo) to have a charge of “impiety” brought against Aristarchos — which, in those benighted pagan times, could mean terminal consequences for a career. (Socrates was executed for “impiety”.) Of course, today, as our readers are aware (e.g., DIO 4.3 §15, DIO 6 §3), we live in an era of free intellectual discourse; for example, even an offense as serious as insufficient brainkissing methods . . . were at hand for determining the sizes and distances of the other heavenly bodies. Indeed, even the order of the planets was a question without a definite answer.

61 If this seem too strong, see Rawlins 1991 and Thurston 1998 SMS & §16.

62 Cubing 10000 yields a trillion — and “Sand-Reckoner” (Archimedes p.232) says that Aristarchos’ stellar universe was a trillion times the Earth-orbit sphere, but without explaining the observational base. Geocentrist preferred rs = ordmag 10000 and extant geocentrist schemes (3 are tabulated in Van Helden 1985 pp.27, 30, 32) placed the stars ordmag 10r distance, while Aristarchos-Archemides held (eq.14) for 10000r and 10000r distance, respectively; so the net heliocentrist-vs-geocentrist stellar-universe linear expansion factor is ordmag (10000/1000) (10000/10) = 10000.

63 The tiny universe-scale dominant among geocentrist reminds one of a joke told by Jake Lamotta about fellow-pug Rocky Graziano. Both were gifted actors after — and before — their retirement from boxing. Jake and professionally-punchy Rocky leave the gym together, and Jake points up into the sky and asks: “Hey, Rocky, what’s that big bright thing — the Sun or the Moon?” Rocky: “Aaaah . . . Aaaah. . . . Awww, Jake, how would I know? I don’t live in this neighborhood.”

64 There are exceptions, for which our gratitude is frequently expressed in DIO.

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Achievement, among the most extraordinary in the history of human thought, merits more than its fate to now: a mere (largely-un comprehending) footnote in science history.

H2 The brains (and their retinue & retiniae), which accomplished this feat, are now dust in the ground — still far from the sky they explored and first comprehended. That dust is even more irrecoverable than the exact details of their original manuscripts, also long gone to dust. But their great discoveries shine on.

H3 For now, this light is darkened and distorted by the turbid, twisted medium of certain modern cultists. (Who do not even appreciate the link between Aristarchos’ work and his vast vision: DIO 4.2 §9 [K13].) Sadly, “for the indefinite future” (DIO 1.2 §3), intelligent scholars must be past (& calibrate for) the wars created by our grant-begging era, when [a] survival priorities swamp concern for truth, and [b] power-first businessman-scholars’ intellectual depth establishes the limit of (public) scholarly debate & consensus.

H4 The modern ironic reality: Aristarchos’ greatness is still being submerged — more than 2000 years after his views’ persecution! — largely because (in 16) grant-raising via Ptolemy’s fatter extrant corpus is more profitable. To put it crudely: there are, numerically, more Ptolemy texts to write theses about. (The advantage this gives to the pretense that geocentrist were genii is, of course, DUE TO two millennia of systematic suppression & banning of heliocentrism by Cleanthes, Ptolemy, the Roman church, etc.) This primitive factor is especially critical when too many of the scholars dominating a field are comparably primitive technically, and so are all too often incapable of going beyond what ancient texts explain in terms simple enough for literal modernities to follow. So, I conclude by suggesting that, in future, our evaluations of scientific heroes be guided not by pre-packaging & §2 item [b] hype-suprelatives imposed from the (political) heights, by the Cleantheatic idea-killers of our own era — but instead by simple considerations of evidence, logic, & decency, mingled with grateful appreciation for the longago adventurous minds who bequeathed us a heritage of high genius and courage, which stands for the best in humanity.

Epilog

Because of some (hopefully ever-more-anachronistically) strong critiques in the foreground, one should understand that it (and other already-published papers on the same subject) evolved over more than 152 (germ published at Rawlins 1991W fn 272), during much of which the Neugebauer clan did what it could to damn the research. But that cultural influence has waned, while among its prime present legacies are G.Toomer’s scrupulous Alm edition, and Toomer’s protégé, the brilliant and creative classicist, Alex Jones, of New York University’s hugely endowed new Institute for the Study of the Ancient World.

Sadly, the Mufa’s former mal-influence has been somewhat replaced by the Gingerich-pawn Historical Astronomy Division (of the unsupervising AAS), whose members’ dissent-courage resembles that described in the latest exposé of sororities. (See Alexandra Robbins Pledged NYC 2004 on their dominatrices & shunnings, e.g., p.128.) Even at its worst, the Mufa at least displayed scholarly dedication. By contrast, much of the ancient astronomy scholarship promulgated by the HAD (using the credulous “science press” whenever possible) is just embarrassingly amateurish. (See, e.g., www.dioi.org/ggg.htm.)

Meantime, however, thanks to Robert Halleux, Dennis Duke, Margaret Rossiter, and Hugh Thurston (among others), the history of science community (which was never comfortable with the Mufa’s arrogance) and DIO have come to appreciate each other, a process which culminated with the contributions to Isis (History of Science Society) by Thurston and DR in 2002-2003. We here thank all those who helped effect this productive amicability, which most of us thought might never come to pass in our lifetimes.

See fn 65. Heath 1913 p.304 (also DIO 1.2 §3) recounts Cleanthes’ attempt (paralleling later threats against Galileo) to have a charge of “impiety” brought against Aristarchos — which, in those benighted pagan times, could mean terminal consequences for a career. (Socrates was executed for “impiety”.)
References

O.Gingerich 1985A. JHA 16:37.
Gerd Graßhoff 1990. History of Ptolemy's Star Catalogue, NYC.
Thos.Heath 1913. Aristarchus of Samos, Oxford U.
O.Neugebauer 1975. History of Ancient Mathematical Astronomy (HAMA), NYC.
D.Rawlins 1982N. ArchiveHistExactSci 26:211.
D.Rawlins 1982A. Queen's Quarterly 91:969.
D.Rawlins 1999. DIO 9.1 §3. (Accepted JHA 1981, but suppressed by livid M.Hoskin.)
D.Rawlins 2002A. DIO 11.1 §1.
Ivor Thomas 1939&41. Ed. Greek Mathematical Works, LCL.
Hugh Thurston 1998A. DIO 8 §1.
Gerald Toomer 1984, Ed. Ptolemy's Almagest, NYC.
B.van der Waerden 1963. Science Awakening I (Tr. Arnold Dresden), NYC.