‡2 Aristarchos Unbound: Ancient Vision

The Hellenistic Heliocentrists' 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 flute!
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 Samos[4] (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 (p.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 3° sunward

[1] Likewise, 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.

[2] From 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 $365^{d}1/4$ 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 scifi 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.

[4] Unlike 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 Samus"? (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[5] 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 [§C3], 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 Muffia — themselves ignore the crucial significance of a glaringly "unhandy detail", the demonstrable falsity of the longtime attribution to Aristarchos of pseudo-Aristarchos' 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:[6] §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.

A2 See OG's similar 1996/8 remarks (12^y after the Zürich meeting) at Gingerich 1996 — projecting his own bizarre Aristarchos-demoting fantasy[7] onto Hugh Thurston, who has informed me, in further astonishment (plus *DIO 6* ‡3 §H1) at the *JHA*'s old habit of careless mentalism (Rawlins 1991W §§B1&B2, *DIO 2.1* ddag 3 §C9), that that this is naturally just Gingerich's imagination at work. Art Levine's satire comes to life yet again in the unique *JHA*![8] What follows will suggest that these Neugebauer-Muffia appraisals are as correct & perceptive as ever. (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: ***rebel&heliocentrist-pioneer Aristarchos was a non-observing fabricator, while go-along-geocentrist&data-faker***[9] ***Ptolemy was antiquity's 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 unique 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 Muffia 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 Muffia orthodoxy in such matters (pp.9-10, emph added):

> [the Aristarchos Experiment] addressed only the problem of the sizes and distances[12] 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, [Muffia] scholars have discovered much about Hipparchus's achievements . . . and how he ***improved on*** Aristarchus's 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 Muffia 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 heliocentrism! (See fn 7.) This is perhaps the most crucial achievement of concept (as against measurement: ‡1 fn 9) made by anyone in ancient astronomy. (See

[5] Indoor-Neugebauer 1975 p.642 astonishingly claims that "one would be lucky to determine the night on which dichotomy falls". Contra this (& fn 19), sharp eyes can discern lunar non-halfness whenever $\gamma >$ Aristarchos' 3°, as DR & K.Pickering have 1st-hand verified 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.dioi.org/fff.htm#hgss]. And note its debts to O.Neugebauer & O.Gingerich: fn 20.) Evans 1992 p.68 still takes the pseudo-A 2° solar diameter bungle so seriously that this author of Oxford Univ Press' *History and Practice of Ancient Astronomy* draws overcertain — not to mention indefensible — conclusions about the evolution of ancient astronomy during its two most productive centuries. (The usual for cultists who think great ancient astronomy only flowered with the faker Ptolemy.) See also fn 16.

[7] If heliocentricity alone is held not to prove that Aristarchos had a planetary theory, we may ask what Plutarch meant by (Heath 1913 p.304) heliocentricity "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 pol-archons' advent, acceptance of (or merely grasping) even elementary ideas has come to require awesome mental struggle.

[8] See *DIO 6* ‡3 fn 11, which relays Levine's spoof of his own *WashMonthly*'s penchant for projection, chuckling that fellow writers reading *WM* accounts of their output "find themselves espousing ideas they've never even heard of, much less agree with."

[9] Ptolemy'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* ‡6 §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 1d/4.) Likewise, to prevent heliocentrist heresy from sullying his readers' minds, Ptolemy at *Almajest* 9.1 discusses the question of whether Mercury and Venus circuit points above or below the Sun — but not the possibility (already entertained by Aristarchos and Theon of Smyrna among others) that these planets' orbital center was virtually ***at*** the Sun. (Similarly, when dispensing with theories that the Earth moves or spins, *Almajest* 1.7 doesn't mention heliocentrism.)

[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 & Efremov 2000 p.133 [which was refereed by Evans]) that Ptolemy was a *better observer than Hipparchos*. Oblivious 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 *Comm* commonly 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* ‡2 §H), Swerdlow 1989, Graßhoff 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 too-easy spoofing by getting into such pretzel-thought?

[11] Despite Rawlins 1991P §F1, 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. Naturally.)

[12] But 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 and Berggren & Sidoli 2007.) Perhaps realization of the contra-outdoor-sky results (§C1) of such calculations stopped pseudo-A from continuing his ms.

§G2 item [c], Rawlins 1987, & Rawlins 1991P.) Yet one looks in vain for mention[13] of it in classic Muffia 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.232). 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.[14] B.Rawlins wonders if selling putative Babylonian originality and genius has led Muffiosi into denigrating Greek empirical work occurring before the central Babylonian astronomical texts' era.) And this realization is (along with §A5) 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 Muffia'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 who suppressed Galileo as the *actual* top intellects of the medieval helio-vs-geocentrist dispute. So, in the field of outrageous historical-revision-apologia, the Muffia outdoes even the master.)

A7 The claim that Hipparchos "improved" heliocentrist Aristarchos' measure of the universe is particularly curious, since Hipparchos and other geocentrists 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, Muffiosi[15] regard it as just a meaningless coincidence that heliocentrists proposed the biggest ancient universe. This achievement, of the finest ancient scientists, is passed off as just primitive, perhaps

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

[14] 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.Newton 1977 p.199 (see also p.173 and R.Newton 1973-4 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 §F5: the coincidence may mean nothing more than that the resulting r_S was the lowest value then current among competent [read: heliocentrist] scientists, which made it current enough even with geocentrists 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 [inaccurate] 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 that ancient's work. (DR's name does not foul a single page of Van Helden 1985. Standard for Muffia 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 1982N as a conscious, Muffia-kissing misleading of the reader, by suppression of evidence against the Muffia view propounded. I.e., the usual.

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

numerological 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 palmed off on the modern scholarly community as the best science available in antiquity,[16] 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 archons he depended upon. Van Helden 1985 p.vii (see also p.168 n.2): "In the course of this project I incurred many debts. . . . A Research Fellowship from the [NEH] . . . . For the medieval and especially the ancient [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[17] "Aristarchos' Experiment" by presuming that Aristarchos had regarded the angular-discrimination limit of man's vision to be about

$$\mu = 1/10000 \text{ of a radian} \tag{1}$$

then (for null visible stellar parallax), shouldn't his distance r_S 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[18] than an AU.

[16] 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 grantsmanship 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' evaluation of Ptolemy has lately been less defensive and more realistic. See esp. Alex Jones' analyses.]

[17] 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 arcsin of the ratio of this to Aristarchos' lunar semi-diameter (1°/4: eq. 3) equals $2°38' \approx 3°$. (Rawlins 1991W §R9's analyses used $0'.4$ instead of 1/10000 of a radian, yielding $2°57'$ 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 arcsin of $0'.45/15'$ is $3°26' \approx 3°$). I found by experiment long ago that the eye's primitive visual limit is about $1'/3$. (The arcsin of this divided by 1°/4 is $2°33' \approx 3°$.) Aristarchos presumably performed just such an experiment to arrive at his value for μ. These estimates agree closely with Dawes' limit (consistent with diffractive Airy disk) for a human eye's pupil-size, and all flutter around $\mu = 1/10000$ of a radian, the value underlying (§B2) all Aristarchan celestial scales. [Note added 2010: Was 87° computed from a null experiment? See www.dioi.org/cot.htm#nxhm.]

[18] The "Sand-Reckoner" development is found in Archimedes (pp.221f) or Neugebauer 1975 (pp.643-647). Aristarchos would (as also Poseidonios: Heath 1913 p.348) likely call 10000 AU a lower not upper limit, but Archimedes prefers the latter (to count sand-grains). The same factor-of-2 ambiguity, which we encountered in a previous paper (Rawlins 1991W §§R9-R11), also exists here (Archimedes p.232 & Neugebauer 1975 p.646). Realizing that the full stellar parallax baseline was really 2 AU (§E4), we see that, by an alternate interpretation here throughout, we could found Aristarchos' universe scale upon the limit of human vision being 1/5000 (not 1/10000) of a radian. Against this is not only fn 17 but also the obvious preferability of whole ordmags — so obvious from Archimedes' "Sand-Reckoner" (which also notes that, at the myriad-mark of 10000, the Greek numerical notation starts repeating itself). On the other hand, if Aristarchos' development employed more exact ratios than powers of 10, these figures might have been rounded to the nearest ordmag by Archimedes. The evidence is not certain, but I lean to believing that the original use of 10000 in eq. 13 was Aristarchos'.

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 was experimentally realized by Aristarchos to be about 1/10000 of a radian, or a little over 1/3 of an arcmin. (And this is about right for raw 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[19] what one would expect of the history of ancient astronomy community as now constituted, since the enterprise is primarily into detailing-repeating 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 at inducing the science[20] behind either A or B. (Muffia disability here is seasoned with naked contempt[21] for nonMuffia scholars who try.) Such work is more apt to encyclopedist-bibliographers, than to thinking scholars. (Few Muffia capos are scientists. They naïvely presume that some mathematics background will suffice to protect[22] 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 millenia, since Eratosthenes (‡1 fn 3) and Pappos (Rawlins 1991W fn 220), the allegedly Aristarchos work, "On the Sizes & Distances of the Sun & Moon", has been universally accepted[23] as genuinely his. Rawlins 1991P (fn 6) and Rawlins 1991W (§R10 & 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 $1/15^{\text{th}}$ of a zodiacal sign or 2° wide in angular diameter (nearly 4 times the correct value), thus pseudo-A's semi-diameter was:

$$\theta_{\text{p}} = 1^\circ \tag{2}$$

obviously false & explicitly contradicted by Archimedes, who reported[24] that Aristarchos' solar diameter was instead the very accurate value $1^\circ/2$ (vs actually $32'$), thus semi-diameter

$$\theta_{\text{A}} = 1^\circ/4 \tag{3}$$

Rawlins 1991P fn 6 eliminated the contradiction by proposing that the factor-of-4 error was based on misreading the Greek word μερος ("part") as a zodiacal sign (30°) rather than the Greek-measure unit called "part" ($7^\circ 1/2$: Neugebauer 1975 pp.652 & 671).
[b] Lunar eclipses can last ***half a day*** (vs 4^{h} in reality: §C8.)
[c] Mean lunar parallax is c.3°. (Actually under 1°.) So an equatorial observer would see the Moon move (net) barely 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 $1^\circ/2$.
[e] In Mediterranean climes (or nearer the Equator), the upper-culmination Moon MUST DAILY BE OBSERVED MOVING IN RETROGRADE[25] against the background of the stars. (Already noted at ‡1 fnn 3&5.) Though this is an inevitable consequence of pseudo-Aristarchos' work, it has not been noticed by centuries of commentators, from Eratosthenes (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*.")[26]

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[27] (*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.

[19] 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., §§A3&A7) with genuine science, one can readily understand how this clique got into the habit of scoffing at the very idea of attempting to relate real science to ancient texts. See, e.g., Gingerich 1976's hyperagnostic-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 naïvete to the realities of §F9 and ‡1 §I3.) This astonishing bit of mis-megahistory (definitively vaporized at ‡1 §§I3&K4 and fn 9) was dished up to excuse Ptolemy's *Almajest* 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 rationalization appeared in the American Association for the Advancement of Science's main organ, *Science*. And it reflects official editorial policy at OG'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 20^{th} century archons slighting 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 1993D §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 nonMuffiosi not to emulate such arrogance and to instead appreciate that even illmannered 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 artificiality has been a contributing factor in judgement-degeneration that has cursed modern history of ancient astronomy.

[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 1913 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 Timocharis & Aristyllos) used degrees: note that the various empirical magnitudes surely connected to Aristarchos are all easy fractions or multiples of degrees: $1^\circ/2$ (solar diameter), 3° (half-Moon vs quadrature), & $10^\circ 2/3$ or $32^\circ/3$ (saros remainder: Rawlins 2002A eq.6). [Note added 2011. Archimedes'(p.224) sunwidth limits, rt.angle fractions 1/200&1/164: $1^\circ/2 \pm 1^\circ/20$.]

[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.sci 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-J.HA 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.dioi.org/jha.htm#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[e]) comes about. Pseudo-Aristarchos' implicit[28] mean lunar distance is (eq.5) $r_{\rm M} = 20^{\rm e}.10$ (where $1^{\rm e} = 1$ Earth-radius). But it is well-known that the Moon's sidereal period is & was $27^{\rm d}.32$ (mean sidereal motion $0^\circ.549$/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[29] than the Moon, which will thus appear to be moving in reverse at about $0^\circ.2$/hr — the peak-speed of a (diurnal-synodic) retrograde loop (similar to the annual-synodic retrograde loops familiar to planet-watchers).[30]

C4 Recall another serious problem with the pseudo-A work. We will define γ as the half-Moon's angular distance from quadrature. Rawlins 1991P §C1 suggested[31] that the famous Aristarchos value

$$\gamma_{\rm A} = 3^\circ = \arcsin(r_{\rm M}/r_{\rm S}) \doteq \arcsin(1/19) \tag{4}$$

was an upper bound, not a precise figure. (The notation: $r_{\rm M}$ = the Moon's distance, and $r_{\rm S}$ = the Sun's distance.) Even allowing this,[32] Rawlins 1991W fn 272 showed that as merely

[28] Heath 1913 p.339 & Neugebauer 1975 p.637 perform the same math, understandably with less precision.

[29] The pseudo-Aristarchos Moon, at mean geocentric distance $20^{\rm e}.10$, 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 $19^{\rm e}.1$ distant 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 ($0^\circ.549$) or: $-0^\circ.2$. (Obliquity's cos = 92%, ignorable for rough mean-situations: [a] when the Moon is on the celestial Equator, its motion is not parallel to the terrestrial observer's equatorial motion; [b] when the Moon's geocentric motion is parallel to the Equator, the Moon is not on the Equator.)

[30] 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 $60^{\rm e}$ (not $20^{\rm e}$) away from the Earth's center — not fast enough to overcome the Moon's own sidereal motion. For the real overhead equatorial Moon at mean distance & mean sidereal speed, the equatorial observer will be traveling only 27.4/60.27 times the Moon's sidereal speed, so the Moon's absolute topocentric $0^\circ.56$/hr speed is slowed to a relative angular speed of about $0^\circ.3$/hr. (When the Moon is near the equatorial nadir, this relative speed would be seen — if it were visible — to be $0^\circ.8$/hr. Over time, the speed must of course average out to the mean lunar geocentric sidereal speed: $0^\circ.549$/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 $r_{\rm M}$. Yet another reason for the incredibility of the wildly false values for $r_{\rm M}$ entailed by pseudo-Aristarchos. Without, that is, both the emendations here suggested (in θ & υ), which lead to the reasonable values found in eq. 11.

[31] A weird variant of DR's upper-bound approach (to explaining Aristarchos' 3°) 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 $\gamma_{\rm A} = 3^\circ$ 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.

[32] 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 might seem 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 §C5] 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° figure depends upon visual discernment of ordmag 1/10000 of a radian — c.$1'/3$, 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 (‡1 eq.14) that Eratosthenes placed the Moon at a distance of 19 Earth-radii, a figure presumably gotten from pseudo-Aristarchos. (Unless universe-shrinking Eratosthenes was himself pseudo-A. The document's curiosities [e.g., ‡1 fn 4] cannot be traced back beyond Eratosthenes.)[33] And this is the figure computed from pseudo-A's propositions 11&17 at Heath 1913 pp.338-339. Yet Heath bases this upon averaging depressingly crude brackets associated with needlessly pedantic geometric proofs. By contrast, an exact computation (e.g., Neugebauer 1975 p.637) finds 20 Earth-radii instead of 19:

$$r_{\rm M} = \frac{1+\sin\gamma_{\rm A}}{(1+\upsilon_{\rm p})\sin\theta_{\rm p}} \doteq 20^{\rm e}.10 \tag{5}$$

using pseudo-A's false data (§C8 & eq.2): shadow-Moon ratio $\upsilon_{\rm p} = 2$ and solar semi-diameter $\theta_{\rm p} = 1^\circ$. Question: if you wished to find 1/sin 1° or (virtually the same) the distance/size ratio for something subtending 1°, wouldn't you just figure that the circumference is 2π times the distance and 1° is 1/360 of that, so distance/semi-diameter $= 360/2\pi = 57.3$? (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 Aristarchos (not knowing where γ was in the range 0° to 3°) simply made it null for solar distance $r_{\rm S} \approx \infty$ ($\gamma \doteq 0^\circ$). In that case, eq.5 becomes:

$$r_{\rm M} = \frac{1+\sin 0^\circ}{(1+\upsilon_{\rm p})\sin\theta_{\rm p}} \doteq 19^{\rm e}.100 \tag{6}$$

(More efficiently: $r_{\rm M} \doteq 60/\pi \doteq 19.1$.) So, Eusebius' verification that a lunar distance of $19^{\rm e}$ 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° figure as exact.

that the early 3rd century BC was the transition period when newly-invented trig was widely but not universally used by mathematicians. Or, Aristarchos may simply have opined that geometric clothing for his demonstration would enhance its academic impact.) [b] The implied visual precision would be impossible, anyway. The range (18 to 20) corresponds to γ equalling $3^\circ \pm 0^\circ.16$ — which in terms of visual discrimination corresponds to half (fn 17) of $1^\circ/4$ (lunar semi-diameter) times sin $0^\circ.16$, or barely $1''$, clearly not visible. Rawlins 1991P §C1 regarded 3° as an upper bound. No other empirical interpretation makes sense. And we now find here that this seemingly speculative interpretation has led straight into realization of its consistency with Aristarchos' other cosmic-measure work: §B1.

[33] 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 2nd half of the 3rd 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°-wide Sun (indeed, he contradicts it), lunar distance $19^{\rm e}$, Earth-shadow/Moon ratio = 2. Note also the clash between Archimedes-Aristarchos (eq.15) and pseudo-Aristarchos (Heath 1913 pp.339 & 350) on $r_{\rm S}$: $10000^{\rm e}$ vs $360^{\rm e}$, respectively. Were Aristarchos' works more welcome in Archimedes' Syracuse than in Eratosthenes' Alexandria (by then of less-Greek rulership, and fiscally strained from funding wars, e.g., Pyrros')? See ‡1 §F3. (What Alexandria instrumental star data survive from the $100^{\rm y}$ after Aristyllos, 260 BC?)

C6 In addition to the flock of pseudo-A difficulties cited above (§C1 & fn 32), Rawlins 1991W §R10 also revealed a hitherto-unnoted 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 work 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]: "μερος") cleared up pseudo-Aristarchos's most obvious absurdity (eq.2: 1° lunisolar semi-diam θ_p), we check another highly suspect pseudo-A statement, namely, that, at the Moon's distance, the pseudo-Aristarchos ratio υ_p of the Earth's umbra (shadow-width) to the lunar angular-diameter is just 2. (Computing with accurate υ is crucial for finding the lunar distance: eq.11.) But this υ would (eq.10) cause central eclipses' Entirety (Partiality + Totality) to be 3 times longer than Totality. Letting ρ stand for the Entirety/Totality ratio, we have pseudo-A's $\rho_\mathrm{p} = 3$ (eq.10). But it is well known that an eclipse's maximum possible Entirety is instead just under 4^h, while maximum possible Totality is slightly more than $1^\mathrm{h}3/4$ — that is, roughly 2^h — creating an Ent/Tot ratio ρ of barely 2 (far short of Ent/Tot = 3). For the mean distance situation, the actual shadow/Moon ratio υ is 2.7 (corresponding to Ent/Tot ratio $\rho = 2\,1/6$: fn 35). And we know that Hipparchos used $\upsilon = 2.5$ (*Almajest* 4.9), while Ptolemy used $\upsilon = 2.6$ (*Almajest* 5.14). So, how could an observing astronomer set $\upsilon = 2$?! The basis for estimating υ is eclipse records. (And Aristarchos may have researched and drawn wisdom from such records more than 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 duration data from such central events, one may (eq.7) compute υ from the ratio ρ of the time of an Entire umbral eclipse to time of Totality (for central eclipses), which is (crudely) $4^\mathrm{h}/2^\mathrm{h} \doteq 2$, a figure that reveals (via eq.7) υ 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 $-286/5/20$ ($\rho = 2\ 1/5$); and-or the 19-digit eclipse of $-279/6/30$ ($\rho = 2\ 1/4$), which occurred just a few days after his famous S.Solstice observation. Such easy observations would make it clear that υ was nowhere near 2. One possible cause of pseudo-A's wacky $\upsilon = 2$ is amateurish confusion: pseudo-A carelessly took ρ (something about in-shadow, wasn't it . . . ?) to be υ. (We already know from §§A1&C1 how easily confused pseudo-A was.) *Keep in mind: the Entire/Totality ratio ρ is an easy raw-empirical number, while υ is derivative.* Another possible explanation of the pseudo-Aristarchos υ-vs-ρ foulup arises quite naturally from an examination of the neat inter-relationship between υ and ρ:

$$\upsilon = \frac{\rho + 1}{\rho - 1} \qquad\qquad \rho = \frac{\upsilon + 1}{\upsilon - 1} \tag{7}$$

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

$$y = R(x) = (x + a)/(x - 1) \tag{8}$$

[34] It is possible that pseudo-A was an uninformed hyperpedant (as Neugebauer 1975 p.643 speaks of Aristarchos, believing him to be the author of "Sizes") — as politically powerful as he was incompetent. Poseidonios is also connected (Neugebauer 1975 pp.654) to $\upsilon = 2$, perhaps while assuming cylindrical shadow (which ON naïvely relates to null parallax). Did $\upsilon = 2$ evolve from such mis-geometry? Alternate route: if a key pseudo-A slip miscontrued $r_\mathrm{S}/r_\mathrm{M} = 19$ (eq.4) as $r_\mathrm{M}/R_\mathrm{Earth} = 19$ (eq.6), then eq.6 could have produced $\upsilon = 2$. (Less likely: eq.10 and $r_\mathrm{M} = 19^\mathrm{e}$ [into eq.6] caused $\theta_\mathrm{p} = 1^\circ$.)

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

$$\text{If } y = R(x), \text{ then } x = R(y).$$

C10 Had the real Aristarchos genuinely believed υ = 2, he must have realized that this correlated (again via eq. 7) to ρ = 3 — which was plainly false, as anyone of the slightest experience with eclipse records would know. But we recall (§C8) that actual ρ just[35] exceeds 2, and no lunar eclipse datum is easier to find. Thus, it is not credible that Aristarchos would opt for ρ = 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 $\rho = 4^\mathrm{h}/2^\mathrm{h}$ ratio noted in §C8 as too plain to miss, that is: $\rho_\mathrm{A} = 2$. And this entails (via eq. 7) a comparably better value for the shadow-moon ratio υ_A, so we can be pretty sure Aristarchos used:

$$\rho_\mathrm{A} = 2 \qquad\qquad \upsilon_\mathrm{A} = 3 \tag{9}$$

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

$$\upsilon_\mathrm{p} = 2 \qquad\qquad \rho_\mathrm{p} = 3 \tag{10}$$

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 ρ (commonly known to be about 2) as a reference to υ, or
[b] simply confused Aristarchos' $\rho_\mathrm{A} = 2$ & $\upsilon_\mathrm{A} = 3$ 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 equation[36] (e.g., eq.5) and thus obtain:

$$r_\mathrm{M} = \frac{1 + \sin\gamma_\mathrm{A}}{(1 + \upsilon_\mathrm{A})\sin\theta_\mathrm{A}} \approx 60^\mathrm{e} \text{ or } 57^\mathrm{e} \tag{11}$$

for $\gamma_\mathrm{A} = 3^\circ$ (eq.4) or $\gamma_\mathrm{A} = 0^\circ$ (eq.6), respectively. Both r_M are correct within c.5%. (Moon's actual mean distance: $60^\mathrm{e}.27$. It should be kept in mind that $r_\mathrm{M} \doteq 60^\mathrm{e}$ 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 was known to within a few Earth-radii in 280 BC — after all, it depends critically (in eq. 11) only upon υ (or ρ) and θ; 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^e: §C3 & eq.5) — or even a factor as large as 4/3 (80^e: Rawlins 1991W eq.31) — is difficult to countenance, since these blunders would require almost impossibly large errors in ρ and (especially) θ.

D Solar System Scale

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

$$r_\mathrm{S} = r_\mathrm{M}/\sin\gamma_\mathrm{A} \approx 60^\mathrm{e}/\sin 3^\circ = 1146^\mathrm{e}\ \ [\approx 1000^\mathrm{e}] \tag{12}$$

[35] In reality, mean $\rho \doteq 2\,1/6$, as one will find from a glance through an eclipse canon or by substituting υ = 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 θ.

(The obvious large uncertainty in γ justifies rounding[37] 1146^{e} to 1000^{e}.)
Such a step could have triggered the later tradition — discovered at Hipparchan eqs.23&24 of Rawlins 1991W — of dividing[38] the AU into units of thousandths: 1 AU = 1000^{a}.)

D2 About 900 AD, Al-Battani's solar work, explicitly building upon the remains of Greek solar theory, exhibited precisely $r_S = 1146^{e}$ (and failed to supply coherent justification for the choice: fn 39). This suggests (though it hardly proves)[39] that 1146^{e} 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^{e} (Heath 1913 p.339 or Neugebauer 1975 p.637 eq.20, computing exactly) and, quadruple that, 1536^{e} (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 adopted here, namely eq. 3.) However, neither of these 2 values is directly attested. Thus, given Al-Battani's use (§D2) of 1146^{e} (eq. 12), we may conclude that: [a] the value 1146^{e} 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 Seagoat: Expanding the Universe a Trillion Times

E1 The irony is that Aristarchos' famous Experiment was far inferior[40] to his greatest heliocentrist 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 geocentrists had realized.

E2 How much greater? Well, according to Archimedes (d. 212 BC), the previous (& still then-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 1/10000 of a radian for that limit. Thus, from eq. 1, he would have set

$$r_s = r_S/\mu = 10000 \cdot r_S = 10000 \text{ AU} \tag{13}$$

So it is gratifying to find this result is actually ***testified to*** (§B1) as a limiting distance by Archimedes' "Sand-Reckoner".[41] 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] 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 (α^1 & α^2 Cap, respectively) was merely 5 arcmin: $3'.7$ in longitude, $3'.3$ in latitude.[43] The searched-for relative parallactic motion would be almost entirely in longitude. Yet it is certain[44] that no such relative motion was ever observed. An ancient might alibi 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 same[45] distance or [ii] stars' remoteness & thus invisible parallax. The former option would probably be rejected:[46] if the seven "planets" were all at different distances, why should thousands of stars all be at only one distance?[47] If Giedi's nearer star (α^2 Cap)

[37] The hypothetical rounding of $r_S = 1146^{e}$ (to 1000^{e}) would produce a slight inconsistency in eq. 12, but (for $r_M = 60^{e}$) would yet imply $\gamma_A = 3°26' \approx 3°$. Note that 1146^{e} is much nearer 1000^{e} than any previous scholar's estimate of Aristarchos' value for r_S: §D3. From fn 18 or eq. 13, we see that Aristarchos ultimately may have ordmag-rounded r_s/r_S to 10000. In any case, Rawlins 1991W eqs.23&24 prove that he (at least initially) and-or later followers rounded 1146^{e} to the nearest ordmag, 1000^{e}, or divided the AU into a thousand milli-AU: 1000^{a}. Whether or not these ancients' micro-measure was Earth-radii, the 1991 analysis shows that their macro-measure was heliocentrically AU-based.

[38] Whatever its origin, this standardization does not imply perpetual consistent identification of 1^{a} with 1^{e}, though such an equation may well have had at least passing popularity. It seems that, during the 3rd century BC, r_S was initially (from Aristarchos' Experiment) set at ordmag 1000^{e}; and then later (due to failure to observe planetary diurnal parallax, as noted here at §F), heliocentrist astronomers (contra geocentrists: §F5) enhanced r_S an ordmag, up to 10000^{e} — the same Archimedian myriad ratio also adopted for r_s/r_S at eqs. 13 & 14.

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

[40] The intimate relation of Aristarchos' Experiment to heliocentricity is seldom mentioned in modern textbooks (perhaps due to the ironic geocentrist-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!

[41] Archimedes (p.232): Neugebauer 1975 (p.643) calls this his most famous work, even while not realizing its empirical significance.

[42] *PlanHyp* 1.2.5 has some speculations on celestial bodies' volumes. Sun a bit larger than the brightest stars, which themselves exceeded all the planets. Jupiter & Saturn were a little smaller, yet still much bigger than Earth. Notably for a geocentric work, Ptolemy had even Mars slightly larger than Earth. (And c.60 times bigger than Venus.)

[43] From the excellent ecliptical tables of K.Moesgaard-L.Kristensen *Centaurus 20*:129 (1976).

[44] Yale BSC parallaxes: for $5\alpha^1$ Cap (HR7747) $0''.006$; for $6\alpha^2$ Cap (HR7754) $0''.034$.

[45] Perhaps to refute arguments such as those considered here, Ptolemy taught that stars were all at one distance (fn 47; *PlanHyp* 1.2, B.Goldstein 1967 p.9, Van Helden 1985 p.24), but ancient opinion was not unanimous. (See J.Evans' new edition of Geminos, or Neugebauer 1975 p.584 n.37a.)

[46] See fn 45 and conclusion of §E3.

[47] Even aside from its Earth-immobility: Ptolemy's conception had all the stars' distances the same (*Almajest* 7.1, Van Helden 1985 p.27), so the Giedi experiment here described would doubly make no impression on him. But one suspects that his demand for uniform stellar distance was designed to defuse (by anticipation) heliocentrists' potentially troublesome parallactic-questions.

were, say, 1000 AU distant and α^1 Cap much[48] 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 $2{\cdot}3438'/1000$ or $7'$. As noted above, the ecliptical component of the $5'$ gap (between the 2 stars comprising Giedi) was $3'.7$ in antiquity. But our hypothesis (1000 AU stellar distance for α^2 Cap) entails $3'.4$ of ecliptical parallax — which thus predicts the unmissable spectacle of α^2 Cap oscillating semi-annually, from ecliptical near-conjunction (October) with α^1 Cap, to being (April) distant by an angle equal to c.1/2 the lunar semi-diameter! Obviously, no such effect was observed — and careful ocular monitoring of Giedi and similar star-pairs would have produced an ample reservoir of null results. For heliocentrists, said null-parallax reservoir would rule out the premis that the stars were merely 1000 AU distant[49] — and thus supplied the empirical basis underlying ancient heliocentrists' *scientific* (not "theoretical")[50] conclusion for eq. 13: stars without annual parallax had to be at least another ordmag distant, namely, 10000 AU.

E5 But we need not speculate on the existence of such observations, since it is obvious from *Almajest* 7.1 (c.160 AD) that, indeed, the ancients had carefully measured lineups and relative positions between stars. And the same source is clear that no such stellar shifts had ever been observed — which is why (until Halley) the stars' relative positions were regarded as "fixed".[51] So the logical conclusion for heliocentric visionaries[52] would be that the stars were roughly 10000 AU distant (or more), as already expressed in eq. 13.

F Later Heliocentric Improvements

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 = Earth radius):

$$r_\mathrm{a}/r_\mathrm{S} = r_\mathrm{S}/R_\mathrm{T} = 10000 \tag{14}$$

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),[53] we know (§F2 & eq. 14) that astronomers did so shortly thereafter.

F2 Kleomedes 2.1 reports (Heath 1913 p.348, Neugebauer 1975 p.656, I.Kidd 1988 p.445) that Poseidonios (1st century BC) considered the possibility that the Sun was (at least: fn 18) 10000^e distant.[54] This is already given in eq. 14, namely:

$$r_\mathrm{S} = 10000^\mathrm{e} \tag{15}$$

[48] Apparently dimmer α^1 Cap is (fn 44) roughly 6 times more distant than α^2 Cap.

[49] To attain to an appropriate perspective on vying ancients' relative intelligence, recall from §A7: [a] Geocentrists were claiming the stars were ordmag 10 AU distant, e.g., Van Helden 1985 pp.27f. [b] The real distance of Proxima Cen, nearest extra-Solar System star, is ordmag 100,000 AU: §A7.

[50] See, e.g., §A1 & fn 20.

[51] *Almajest* 7.1: because the stars "maintain the formations [of their constellations] unchanged and their distances from each other the same, we are right to call them 'fixed'." I believe that most previous historians have examined this statement entirely with respect to proper motion, but have ignored the parallax question which was of at least equal interest to ancient heliocentrist observers. Geocentrists such as Hipparchos & Ptolemy, who have supplied most of our links to serious ancient astronomy, do not relay discussions of star-shifts in this dangerous parallactic connection.

[52] Neugebauer 1975 p.657: Pliny&churchmen "grumbled" at nonutility of seeking universe's scale.

[53] Archimedes ("Sand-Reckoner" p.223) connects Aristarchos to eq. 12, not eq. 15. See fn 32. 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.

[54] Heath 1913 p.348 supposes that the 10000^e figure (for which no sensible Poseidonios evidence survives) is based on Archimedes' "Sand-Reckoner" 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 μ (eq. 1). The further suggestion is that Archimedes' allegedly pure-math exercise actually reflects prevailing heliocentrist opinion, in its double use (eq. 14) of 10000 as the key scale ratio of the system. Note that Archimedes speaks of 10000 as an upper limit for both ratios of eq. 14; but Poseidonios does not do so. He instead goes on (§F2) to propose that stars' sizes can exceed the Sun's. (A similar statement regarding brightness would be more indicative. After all, even Ptolemy taught that stars were nearly as big as the Sun: fn 42, Van Helden 1985 p.27.) This slight alteration may reflect post-Archimedes refinements (e.g., larger terrestrial baseline) for the planet-star occultation observations discussed at §F7.

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[55] that Poseidonios was teaching[56] a heliocentric conception of the universe — as also did Seleukos. (Heath 1913 p.305 cites several of the ancient testimonies on heliocentrists.) And Poseidonios also suggested that the stars can match or even exceed the Sun in size (Neugebauer 1975 p.965).

F3 What can have caused the shift in heliocentrists' adopted r_S from 1146^e (ordmag 1000^e) to 10000^e? The answer is obvious the moment one has recourse to observation, which (if r_S is assumed equal to c.1000^e) produces a reduction to empirical contradiction, similar to that found via Giedi (§E4) by assuming a stellar distance of 1000 AU.

F4 It is a striking fact that all 3 extant reported ancient planet-star occultations are Hellenistic and are near or 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* ‡1 fn 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 Aristarchans were examining planet-star occultations — which just happen to have been the best hope for ancients' gauging r_S in Earth-radii. In a moment, we will show (§F6) how such observations will swiftly eliminate Aristarchos' initial idea that $r_\mathrm{S} = 1146^\mathrm{e}$ (eq. 12). After this value was rendered obsolete, it evidently lingered on anyway among psychologically-receptive geocentrists, e.g., Al-Battani.[57] He, like Hipparchos & Ptolemy, preferred r_S to be as small as possible so the Sun wouldn't be so embarrassingly bigger than the tiny alleged terrestrial Center of the Universe. (And Eratosthenes had the universe even snugger: ‡1 §F3.) Ironically, this geocentrist tradition misled the first modern public heliocentrist, Copernicus, who set $r_\mathrm{S} = 1142^\mathrm{e}$, close to Aristarchos' initial 1146^e value (& not far from Ptolemy's). Later, public-geocentrist Tycho used 1150^e (Thoren 1990 pp.302-304). So: [a] Aristarchos' Experiment was the basis of Solar System scales for nearly 2 millennia, adopted (at least roughly) by Ptolemy, Battani, Copernicus, Tycho, successively. [b] Poseidonios' $r_\mathrm{S} = 10000^\mathrm{e}$ (eq. 14) was, in accuracy, superior to all these later figures.

[55] See the precious puzzlement of Toomer 1984 (p.257 n.66 emph added): "*There is no point* in estimating the relative volumes of the bodies, but it was evidently traditional in Greek astronomy". The incomprehension here (by the very scholar whom Muffia satellite P.Huber calls "*the* expert" on the *Almajest*: PH's emphasis) beautifully typifies the Muffia's uncanny non-intuition regarding what real ancient scientists were about.

[56] Poseidonios taught several conflicting schemes: Neugebauer 1975 p.656. One of his values, $r_\mathrm{S} = 1625^\mathrm{e}$, is more consistent with 1536^e (§D3) than with 1146^e (*idem*). An accurate ancient Earth-circumference is implicit in one of Poseidonios' schemes: 600 stades/degree (Neugebauer 1975 p.656 n.3; or, with p.655 eq.11: 625 st/degr). Yet his math at Neugebauer 1975 p.656 eq.20 presumes 700 st/degr; and Poseidonios is known from Strabo 2.2.2 to have promoted 500 st/degr. Note another 600 st/degr suggestion in Pliny: Neugebauer 1975 p.654. If some ancients got-it-right with 600 st/degr (so 1 nmi = 10 stades wasn't an accident?), had they — possibly suspecting refraction — averaged standard Cs, 252000 stades & 180000 stades (‡1 §§D3&I3) to find accurate $C = 216000$ stades?

[57] See fn 39 & Swerdlow 1968 pp.92-94. I offer a novel speculative explanation of Al-Battani's contradictions: [a] He or a predecessor computed the Moon's distance for solar distance = ∞; using this and Ptolemy's $\theta = 15'40''$ & $\upsilon = 13/5$ in eq. 11, he found (taking 1 radian = $57^\circ 18'$): $r_\mathrm{M} = 1^\mathrm{e}/0^\mathrm{p}59'03'' = 60^\mathrm{e}58'$. [b] Battani then computed $r_\mathrm{S}/r_\mathrm{M} = 1146^\mathrm{e}/60^\mathrm{e}58' = 18\ 4/5$, the ratio gotten at *Almajest* 5.16 via $R_\mathrm{S}/R_\mathrm{M} = 330^\mathrm{p}33'$. (Only safe conclusion: big-coincidence here somewhere!)

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^{e} (eq. 12), the Sun's diurnal parallax is $3'$. 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 $3'$ solar parallax corresponds to about $6'$ of Mars parallax. At Alexandria's latitude, 31°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 $r_S = 1146^{e}$, Mars ought to show ordmag $10'$ 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 Timocharis), Mars' apparent geocentric longitude will vary by merely about half an arcmin over the 48^{h} period around the station (1^{d} before&after). Such stations[58] 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[59] can be more than triple the Sun's. But for $3'$ solar parallax (§F6), Venus' greatest diurnal parallax[60] should be as high as about $10'$. If Venus passed near a star, then one need only compare observations taken, say, at Meroë (latitude L = 17°), vs. ones taken, say, at Byzantion (L = 41°). The north-south angular distance between planet & star at conjunction should differ by about $5'$ — simply detected by the naked eye.

F8 I propose that our fragmentary record (§F4) of ancient planet-star occultations is part of Aristarchans' systematic empirical[61] testing — which eventually converted heliocentrists, c.270 BC (sometime between Aristarchos' Experiment & the "Sand-Reckoner") from $r_S = 1146^{e}$ (eq. 12) to $r_S = 10000^{e}$ (eq. 15). (Such observations, in proving solar remoteness, also proved solar hugeness and thus supported heliocentricity: §F2 & Rawlins 1991P §C3.)

F9 Summing up the evidential situation: we have examined all 3 of the surviving astronomical scales connectable to ancient heliocentrists (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 pregnant 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 §J. 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 theory 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

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

[59] *Almajest* 9.1 taught that planetary diurnal parallax was invisible. (See Rawlins 1991P §F3.) But Swerdlow 1968 correctly notes (p.102) that planetary diurnal parallax "is too large to be ignored" (ordmag 1° for Mercury, in Ptolemy's system) — even though Ptolemy continued to insist (p.103) that such parallax cannot be measured! Ptolemy later admitted (*PlanHyp* 1.2.5, 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] Hartner 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.

1984A p.984, Rawlins 1985K, Rawlins 1985G §5, Rawlins 1991H fn 1, *DIO 11.1-2*, *DIO 13.1*, www.dioi.org/thr.htm.) DR evidently was the 1st to publish these startling facts, since the Muffia had wilfully overlooked this remarkable[62] achievement. After all, the Muffia has decreed[63] in *Science* that accuracy is irrelevant to ancient astronomy.

F10 Since the *JHA* 1980/6 editorial policy statement cited elsewhere here (fn 64) calls it "a mortal sin to judge the present solely in the light of the present", I offer the observation that, by this unexceptionable *JHA* criterion, it would be mortally-sinful if a modern academic cult projected onto ancient scholars its own creative sterility, technical ignorance, and conscienceless amorality. This patently fantastic example is of course purely a DR fabrication, innocently concocted, like Ptolemy's fakes, entirely "for pedagogic purposes" — to borrow the brilliant phraseology of Gingerich 1976.

G The Force of Reason and the Force of Prison

G1 We recall O.Gingerich's suggestion (§A2) that Aristarchos' contributions were minor and off-the-top-of-the-head. Thus, Aristarchos' demotion may be rationalized in the same fashion as the Muffia'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[64] 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[65] succeeded in virtually burying his work — despite his high ancient reputation (Rawlins 1991W §Q1) & achievements[66] — is effectively to endorse dictatorial bullying & idea-imprisonment. I cannot begin to imagine why the Muffia would sympathize with and effectively endorse such behavior.

[b] Must we follow Neugebauer&OG in letting the brilliance, boldness, & vindication[67] of Aristarchos be lost in the celeb-spotlight both men shine instead on astrologer-quackser

[62] 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.

[63] Fn 20. See also Gingerich 1976 (& even valuable Graßhoff 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?

[64] See similar excusing of discovery-misattribution in OG's *JHA 11.2*:145; 1980/6 (statement by Lord H & OG). One senses just how upset the *JHA* Editorship gets at plagiarism.

[65] Fn 69. Plutarch *Moralia* 923, Gingerich 1985A p.39, Rawlins 1991P §G2.

[66] Besides the present findings, see e.g., Rawlins 1991P fn 1 and Rawlins 1991W §N17 & eqs.22-24.

[67] If I 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 (fnn 6, 20, & 64) so knee-jerk anti-judgemental regarding its subjects (*though not its turf-competitors*) that it has lost sight of the fact that vindication-by-future-experimentation is not anachro-twisted mis-history but rather is: [i] what scientists dream of, & [ii] the standard test of scientific theories' truth or falsity. To trace how hist.astron scholars have become 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 & disfunctional 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 oxplo cultists who longed to obscure and alibi the failures & fakeries of astrologers & other pseudoscientists.)

(Rawlins 1984A pp.972, 981) C.Ptolemy: supreme faker, sellout, lawyer-crank, i.e., *the* ideal Muffia choice for its "Greatest Astronomer of Antiquity"?[68] (Neugebauer 1957 p.191 on Ptolemy's *Almajest*: "one of the greatest masterpieces of scientific analysis ever written." Cultist Van Helden 1985 p.41 genuflects to Ptolemy: "the master himself".)

[c] Above, we have found evidence that, even under the shadow of Cleanthes' notorious[69] threat, Aristarchos reasoned out & promulgated the epochal implications of heliocentricity. It is selfevident[70] (§A5) that, e.g., he realized that heliocentricity gave (in AU) the correct distances to the planets (not knowable from Ptolemy's crackpot[71] astronomy), the key step (Rawlins 1987 & Rawlins 1991P) ultimately yielding Kepler's 3rd Law (discovered & suppressed in antiquity?) & so Newton's universal gravitation.

[d] And beyond this, we have the Aristarchos heliocentric theory's more overwhelming implications for the size of the stellar universe, a conception which demonstrably impressed the greatest of ancient mathematicians, Archimedes — an influence which by itself earns Aristarchos first rank even by the *JHA*'s own corrupt criterion (fn 64). Since OG has raised (§G1) the question of the relative superiority of Aristarchos & Copernicus, I will note that Copernicus 1543 (*De Rev* 1.10) did not quantify at all the critical fact that heliocentricity necessitated an expansion of the universe by several orders of magnitude. But, as we have seen (eq. 14), Aristarchos did. Nonetheless, modern hist.astron (e.g., Van Helden 1985 pp.41, 46-47) pretends that Copernicus, not Aristarchos, was the first to realize that heliocentricity implied a huge universe. Well, what else would one expect from a cult which pretends to salvage & purify ancient scholarship, even while trying (*DIO 1.1* ‡1 §C5) to destroy the reputation of any scholar (ancient or modern) whom it happens to disappove of?

H Heroes & Zeros

H1 Since most great work is the tip of a pyramidal anonymiceberg, it is risky (& usually unjust) to single out one figure as The Greatest, in any field. However — despite Cleanthes' worst efforts at grounding him — Aristarchos' wingéd mentality soared beyond his terrestrial confinements of physical gravity and academic bigotry. And he still glimmers, through the haze of our indistinct record, as the ancient astronomer who perceived, proved, & published the realization that the universe's volume is ordmag a trillion (10^{12}) times larger[72] than hitherto understood, which reveals him to have done even more for our spatial perspective[73] than what 19th century geology & biology did for our temporal vision. His achievement, among the most extraordinary in the history of human thought, merits more than its fate to now: a mere (largely-uncomprehending) footnote in science history.

H2 The brains (and their retinue & retinae), 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* §B3), intelligent scholars must see past (& calibrate for) the warps 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 (fn 16) grant-raising via Ptolemy's fatter extant 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 geocentrists 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[74] incapable of going beyond what ancient texts explain in terms simple enough for literal mentalities to follow. So, I conclude by suggesting that, in future, our evaluations of scientific heroes be guided not by pre-packaging & (§G2 item [b]) hype-superlatives 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 foregoing, one should understand that it (and other already-published papers on the same subject) evolved over more than 15^{y} (germ published at Rawlins 1991W fn 272), during much of which the Neugebauer clan did what it could to damn the research. But that cult's censorial 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 Muffia'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 Muffia 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 Muffia'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.

[68] *DIO 1.1* ‡5 fn 24, ‡6 §H7, ‡7 §B2.

[69] See fn 65. Heath 1913 p.304 (also *DIO 1.1* ‡1 §D3) 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 of hist.astron archons will have no effect whatever upon a scholar's career.

[70] Neugebauer-Muffia genii discern none of this. Swerdlow 1968 p.96: "There is nothing even approaching a reasonable theory of planetary distances in pre-Ptolemaic literature." Van Helden 1985 p.9: "Aristarchus's treatise ['Sizes'] . . . addressed only [the Sun & Moon]. No comparable geometric 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."

[71] If this seem too strong, see Rawlins 1991P and Thurston 1998A §M5 & ⊙16.

[72] 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. Geocentrists preferred r_S = ordmag 1000^e and extant geocentrist schemes (3 are tabulated in Van Helden 1985 pp.27, 30, 32) placed the stars ordmag $10r_S$ distant, while Aristarchos-Archimedes held (eq.14) for 10000^e and $10000r_S$ distant, respectively; so the net heliocentrist-vs-geocentrist stellar-universe linear expansion factor is ordmag (10000/1000)·(10000/10) ≈ 10000.

[73] The tiny universe-scale dominant among geocentrists 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. . . . Aaaaah. . . . Awww, Jake, how would I know? I don't live in this neighborhood."

[74] There are exceptions, for which our gratitude is frequently expressed in *DIO*.

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