

## ‡9 Accurate Ancient Astronomical Achievements

### History of Astronomy Cult: In-Denial and In-Denial

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by

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### A History-of-Science's Persistent Mis-Denigration of Greek Science

**A1** Histories of ancient Greek astronomy routinely describe it as inaccurate, geocentrist, and so nonempirical that Greek scientists allegedly destroyed data conflicting with prevailing theories. Prominent denigrations: Neugebauer 1975 pp.108, 284, 642-643; Gingerich 1976 p.477; ScAm 1979; Van Helden 1985 pp.6-7 and 167 n.8; Evans 1987; Evans 1992 p.68; Evans 1998 pp.273-274 & n.32; Duke 2008W p.287; Shcheglov 2016 pp.687&693.

**A2** Such unhinged speculation is contrary to a broad range of easily verifiable aspects of ancient science. Greek astronomy was sufficiently competent that it determined a surprising number of celestial and geographical quantities, to virtually the limit of pre-telescopic possibility. E.g., the Moon's distance was found by eclipse analysis (R.Newton 1977 p.174 Fig.VIII.2) to 2% accuracy, 59 Earth-radii (*Almajest* 5.13) vs actually 60; the mean motion of Mars (*Almajest* 9.3) was found (by stationary points: Neugebauer 1975 p.390) to c.1' per century; the Sun's angular diameter was correctly observed (Rawlins 2012T eqs.8-9) by Archimedes as between 27' & 33'. (Full list of Greek accuracies: Rawlins 2018A §B.)

**A3** But the alert reader may already have discerned an enlightening contradiction in the foregoing brief introduction, namely: *how could Greek astronomers advance to numerous highly accurate measurements by just mimicking the results of their predecessors?*

### B Ancients' 3 Adopted Monthlengths Good to 1 Time-Sec or Better

**B1** The Greek achievement that is most surprising, to those who are not familiar with ancient science (and even to some who think they are), is the 3<sup>rd</sup> century BC estimate of the length of the synodic (civil) month, good to one part in several million, by Aristarchos of Samos, also famous as the 1<sup>st</sup> to teach that the Earth goes around the Sun.

**B2** How was such accuracy possible in an era without telescopes or reliable clocks? Simple: as told at *Almajest* 4.2 (2<sup>nd</sup> century AD), ancients had noted a 4267 month eclipse-return cycle (nearly 345<sup>y</sup> long) which happened to coincide so near-exactly with 4573 anomalistic months, that the time of the interval between eclipses was virtually invariant no matter where on the ecliptic the eclipse-pair occurred, or when. (The anomalistic month is the mean time for the Moon's return to its apogee.) Centuries of eclipse data preserved at Babylon (*Almajest* 4.11), compared to like data from classical antiquity, showed that the 4267 month eclipse-pair interval never varied by more than a fraction of an hour from a mean of 126007<sup>d</sup>01<sup>h</sup>. Dividing this by 4267 yielded 29<sup>d</sup>12<sup>h</sup>44<sup>m</sup>03<sup>s</sup>.3. Sure enough, we find a monthlength of 29<sup>d</sup>12<sup>h</sup>44<sup>m</sup>03<sup>s</sup>1/3 explicitly attested on cuneiform text BM55555 (c.100 BC). Also at *Almajest* 4.2 (c.160 AD), which says: [1] that this was the monthlength of Hipparchos (c.130 BC), and [2] that the 223 month saros expression, which has been (Heath 1913 pp.314f; Rawlins 2002A §A) mathematically traced to Aristarchos (280 BC), was 18<sup>y</sup>10<sup>m</sup>2/3, one 223<sup>rd</sup> of which is 29<sup>d</sup>12<sup>h</sup>44<sup>m</sup>03<sup>s</sup>.2, agreeing to 1 part in 24 million with the "Babylonian" value, the difference just a rounding-imprecision. The Aristarchan monthlength, later adopted by Babylon (c.200 BC) and even later by Hipparchos, was correct to a fraction of a second — the actual synodic month then being equal to 29<sup>d</sup>12<sup>h</sup>44<sup>m</sup>03<sup>s</sup>1/2.

**B3** Since 4267 synodic months equals 4573 anomalistic months, removing common factor 17 (*Almajest* 4.2) produced the famous relation 251 synodic months = 269 anomalistic months. So ancients simply multiplied 251/269 times §B2's synodic month, to determine that the anomalistic month = 27<sup>d</sup>13<sup>h</sup>18<sup>m</sup>35<sup>s</sup>, just 1<sup>s</sup> less than the truth then.

**B4** The draconitic (eclipse) month is the mean time for the Moon's return to a node, where eclipses can occur. The method of determining its length is provided at *Almajest* 6.9, where Hipparchos preliminarily chooses an appropriate eclipse-pair, Babylon-observed -719/3/8 and Hipparchos-observed -140/1/27, separated by almost exactly 7160 synodic months and 7770 draconitic months, so the eclipse month would be 716/777 times the synodic month, or 27<sup>d</sup>05<sup>h</sup>05<sup>m</sup>37<sup>s</sup>.0, too high by 1<sup>s</sup>. But, realizing that a longer interval would improve accuracy, Hipparchos switched (Rawlins 2002H eqs.1-3) his choice of prior eclipse back to the now-lost Babylon eclipse of -1244/11/13, establishing that 13645 synodic months equalled 14807 1/2 draconitic months, which after division by 5/2 produces the ratio 5458 synodic months = 5923 draconitic months, attested at *Almajest* 4.2. So Hipparchos could just multiply §B2's synodic month by 5458/5923, to find that the draconitic month = 27<sup>d</sup>05<sup>h</sup>05<sup>m</sup>35<sup>s</sup>.9, off by but a fraction of 1<sup>s</sup>, the actual value then being 27<sup>d</sup>05<sup>h</sup>05<sup>m</sup>36<sup>s</sup>.

**B5** One may reasonably inquire of those who keep on teaching that Greek science was non-empirical: are they seriously contending that all three Greek-adopted ancient monthlengths were correct to 1<sup>s</sup> or better

### BY ACCIDENT?!

### C Two Related Cases of 1% Precision — But Systematic Inaccuracy Eratosthenes' Earth-Size Error Unfaced by Metrological Loyalists

**C1** The weird exception to mob-insistence on Greek inaccuracy is modern fealty to the famous myth that Eratosthenes measured the Summer Solstice Sun's *ZD* (zenith distance, or angular distance from overhead) at Local Apparent Noon (LAN) in Alexandria as 1/50<sup>th</sup> of a circle while at Aswan's LAN, 5000 stades further south, the Sun was overhead (*ZD* = 0°), so he computed that the Earth's *C* is 50 times 5000 or 250000 stades (Kleomedes 1.10). That is 16% higher than the actual *C*, 216000 stades, since the royal stade was 185 meters. But an unending succession of modern scholars have tried to justify it anyway, shrinking the stade **solely to fit Eratosthenes**. The resulting conveniently-small, perfectly mythical "Eratosthenian" stade is on permanent fanatical display in Wikipedia. For the most thorough demonstration that it has always been fiction, see Engels 1985 p.309's table.

**C2** The difficulty for stade-scrunchers is that there were not one but two successively-adopted standard ancient values for Earth's circumference: Eratosthenes' too-high 250000 (or so) stades in the 3<sup>rd</sup> century BC; and Poseidonios' later (1<sup>st</sup> century BC) too-low 180000 stades (Strabo 2.2.2.). The latter was used in the *Geographical Directory* (*GD*) or "Geography" of astrologer Claudius Ptolemy (c.160 AD and no relation to the Ptolemies who ruled Egypt centuries earlier), which was dominant for 1000<sup>y</sup> until the Renaissance. A lethal impediment to flexing the stade is that if one chooses a stade smaller than 185m in order to improve 250000 stades' fit to reality, this simultaneously degrades 180000 stades' fit. And vice-versa.

**C3** But, as ‡8 [ & Rawlins 2018V] demonstrate, there is a potential solution that, even while requiring none of the traditional *ad hoc* shrinking of the 185 meter stade, *simultaneously solves both disparate standard ancient Earth-size values*. **Despite their 40% disagreement**. Without exception, historians-of-science ignore this solution (assuming they even understand the physics), though for nearly 40<sup>y</sup> pieces of it have appeared in various prominent science sources. (Rawlins 1979. *Scientific American* 1979 May. Later, Thurston 1994E p.120. D.Halliday, R.Resnick, & J.Walker 1997 *Fundamentals of Physics* 5th ed. p.7 & sunset frontispiece. Also www.dioi.org/vols/we0.pdf, Rawlins 2008Q eq.28.) This easy solution is merely: *airbending of horizontal light* (atmospheric refraction). But: just how well does this approach satisfy the 2 attested ancient standard Earth-sizes?

**C4** We have 2 independent evidences (Rawlins 1982N eq.4; Rawlins 2008Q eqs.10-11) that Eratosthenes' raw empirical circumference estimate was not 250000 stades or 252000, but 256000, which is **19% or nearly 6/5 too high**, while Poseidonios' 180000 stades is **exactly 5/6 too small** — a striking inverse-symmetry *based on the ratio of 6 to 5*.

**C5** These numbers fall right in line with a very simple, spare physical explanation. Sealevel horizontal light is airbent with curvature virtually 1/6 of the Earth's curvature. Thus, for over 100', navigation manuals have recognized that geometric calculation of the horizon's distance needs adjustment by factor  $\sqrt{6/5}$  (S.Newcomb 1906 p.203).

**C6** Provocative coincidence: the wondrous Pharos lighthouse at Alexandria *was built at the very time&place of the Eratosthenes C's appearance* (see www.dioi.org/jq00.pdf, §G3 for Shakespeare→Marlowe parallel confluence), and the distance of its flame's visibility could measure Earth-circumference *C*. (Ancients were aware of such outdoor testing, knowing that a light hung in a receding ship's mast eventually disappears due to the Earth's curvature: Pliny 2.65.164.) But the lighthouse-flame method would yield a size 6/5 too high, since its computation (Rawlins 2008Q eq.2) of the Earth's radius results from squaring the flame's visibility-distance *in stades*, which also squares §C5's  $\sqrt{6/5}$  expansion-factor for *v* — thereby multiplying the geometrically-calculated radius (*idem*) by 6/5.

**C7** But there's an alternate equally precise (and comparably inaccurate) stay-at-home method: a sunset seen from the Pharos' top occurred *more than a time-minute* after one seen from the sealevel base, an easily repeatable empirical measure which would yield an Earth-size too low by 5/6, since computation of Earth's circumference from the twixt-sunsets time-interval (which is proportional to the horizon's  $\sqrt{6/5}$ -enhanced distance seen from the higher perch) requires division by its square (Rawlins 1979 eq.13). (See fun demo-by-extremes, showing why flame & double-sunset results hugely disagree, at †8 §C.) The 180000 stade circumference probably appeared historically later than 256000 stades primarily because the smaller value's calculation needed spherical trig (Rawlins 1979 Tables I&II), for which there is no evidence of existence (§14 below) as early as Eratosthenes.

**C8** The triple-match of theory to *both* attested ancient Earth-sizes *and* to the 185 meter stade — to 1% in all 3 cases — provides [a] more evidence of ancient scientists' high scrupulousness & precision, and [b] revelation that modern Eratosthenian-justifier stademaniplulators have spent a century on a fruitless track, as the solution now turns out to be physical not metrological, and is thrice consistent with reality: again, to 1% empirical accuracy. An extra implicit irony: the most famous of ancient astronomical legends, Eratosthenes' experiment, wasn't astronomical.

## D Ancient Observatories' Latitudes Found to Ordmag One Arcmin

**D1** A further irony of the foregoing is easily-missed: none of the narrowly-focused apologia for Eratosthenes' famous supposed Alexandria-Aswan solar experiment have ever noticed that Alexandria & Aswan actually *are* exactly 5000 stades apart in angular latitude, as are Aswan & Meroë. (Rawlins 2009S §C. Strabo 2.1.20.) Both figures are given together at Strabo 2.5.7. By Eratosthenes' 700 stades/degree scale (*idem*), both latitude gaps are 7° 1/7, fitting to c.1' these cities' actual respective north latitudes, 31° 12', 24° 05', 16° 57'.

**D2** Rounding-accident? No, Greek astronomical latitude-fixes were really that reliable. Misled by the disgraceful ordmag 1° errors in astrologer Ptolemy's *Geographical Directory*, scholars were unaware of this ere 1982. But statistical investigations during that year, Rawlins 1982G n.17 (& Rawlins 1982C Table V's solutions for *y*), confirmed later by Maeyama 1984 & Brandt *et al* 2014B, have consistently found that all 4 of the astronomers, c.300 BC to c.160 AD, whose star data survive at *Almajest* 7.3&5-8.1, fixed their latitudes to ordmag 1' (1 nautical mile), pretelescopic vision's rough limit. (Declination-based results summarized at Rawlins 1994L Table 3; improved at Rawlins 2018D Table 1.) As early as c.300 BC, Timocharis, 1<sup>st</sup> of the 4, knew Alexandria's latitude exactly: 31° 12' (§F2).

## E Ancient Longitude Accuracy by Lunar-Eclipse Comparison History-of-Science's Backfiring Denial of the Achievement

**E1** Running a least-squares on a 16-city sample, Rawlins' 1984 Greenwich Meridian Centenary speech showed (Rawlins 1985G eq.16) anciently tabulated Mediterranean longitudes, from the Roman-Carthaginian region east, were consistent with Greek scientists' ordmag-1°-accurate longitude determinations by comparing lunar eclipses' local times, assuming these had been ignorantly (Rawlins 2018A §F) multiplied by 4/3 or 7/5 by Ptolemy (or Marinus) before coming down to us in his *GD*. This conclusion fits several evidences: [a] The lunar-eclipse method is explicitly recommended by Hipparchos (Strabo 1.1.12). [b] The mean error is roughly as expected for eclipse-based data (Rawlins 1985G §9). [c] Absolute errors of longitude gaps are independent of gaps' sizes (Rawlins 2018A §O), as they should be if eclipse-time-based.

**E2** In late 2016, history-of-science's toppe journal, *Isis*, launched an insulting, fake-refereed (Rawlins 2018A Postscript) attack on these solid findings as merely a "delusion", an attack (Shcheglov 2016) revealing that both the author & *Isis* Editor H.F.Cohen lack the most elementary math-science skills. Cohen leapfrogged beyond the sin of non-refereeing by proceeding on to naked coverup, refusing even to acknowledge receipt of our 2017/2/27 letter to him, www.dioi.org/isx2r.pdf, alerting him to *Isis*' 2015&2016 misadventures, or our 2017/3/20-4/1 letter (Rawlins 2018A) to *Isis*' Board, www.dioi.org/islg.doc, correcting Shcheglov 2016 n.8's false science in his claim that eclipse-time-gap reports by Kleomedes & Pliny are "badly overestimated". His lethally central, truly astonishing errors (in the sole scientific evidence he brings against Rawlins 1985G): [1] uncomprehendingly treating a solar eclipse as lunar; [2] placing Spain (& two Chinese cities) into the wrong hemisphere.

**E3** Incredibly, anyone reading the *Isis* author's own citations (Shcheglov 2016 n.7), to esteemed historian-icon Neugebauer 1975 pp.668&844-848, watches Neugebauer overturn all of Shcheglov's contentions regarding "badly overestimated" eclipse-gaps, just as at Rawlins 2018A §D. So the data esteemed *Isis* **carelessly, ignorantly** threw at long-resented but maddeningly-invulnerable Rawlins 1985G redounded — telling all who's Delusional.

## F The 185-Meter Stade: Its Long-Unrealized Potential Implications One More Hint of 1% Precision — Plus Like Accuracy in This Case

**F1** But how arose the royal Alexandrian 185 meter stade so prominent in §C above? There is much ancient testimony (Strabo 2.5.7; Neugebauer 1975 pp.590 [n.2], 733, 1364 Fig.43) that 300 BC Greek geographers divided terrestrial meridians into 60 parts, not 360. Given that standard Hellenistic fractionalization was sexagesimal, the search for smaller geographical units would continue successive divisions by 60. If the early Ptolemies' surveyors had wished to define a royal stade, they would have done so much as later scientists did — when they defined the meter or the nautical mile — and kept dividing Earth's circumference by 60 until finding a suitable unit. To check the theory, thrice divide 40000000 meters by 60. Result: 185 meters. Admittedly speculative, **this is nonetheless the sole available scientific theory explaining that central Greek unit**. Its implications are even more provocative: how could Greek scientists have found the Earth's circumference to a fraction of 1%? Did Ptolemy I order his new empire surveyed? Martianus Capella 598 refers to "King Ptolemy's surveyors"; and Kleomedes 1.10 hints at such.

**F2** The one known Alexandrian scientist (of the four cited at §D2), who, via ringed instruments, measured (Rawlins 1994L §F6) his city's exact latitude correctly on-the-nose as 31° 12', flourished at the time of Ptolemy I — Timocharis. His —302-271 observations of stars, Moon, & Venus are remembered at *Almajest* 7.1-3 & 10.4. He clearly had the talents and experience to supervise a hypothetical survey, including precise odometer-measure of a meridian arc of 1578 km, traveling (via camel?) from Alexandria due south (along longitude 29° 9 E), *without interruption by the Nile*, to the pre-measured (Strabo 2.1.20;

Rawlins 2008S §§C2-C3) latitude of Meroë. Both cities' latitudes were indeed accurately known (§D1 here), differing by  $14^{\circ}1/4$ . From such data, simple arithmetic would yield the Earth's circumference:  $360^{\circ}/(14^{\circ}1/4) \cdot 1578 \text{ km} \doteq 40000000 \text{ meters}$ . (And since  $C$  was defined as 216000 stades, a check-multiplication by 185m of course finds 40000000m.)

## G The Earth's Tilt — Hipparchos' 135 BC Measure

**G1** No explicitly attested anciently adopted obliquity was close to the actual value in Hipparchos' time,  $23^{\circ}42'.7$ . But, over  $80^y$  ago, a world expert in ancient geographical mss, Diller 1934, discovered that a dozen (Strabo-preserved) data of Hipparchos indicated that his final observed and adopted obliquity was  $23^{\circ}2/3$  (Rawlins 2018C Table 1).

**G2** If obliquity was accurately measured by the standard solstitial method (*Almagest* 1.12), then, accounting (as at §H3) for atmospheric refraction, the result when ancient-conventionally rounded to the nearest  $5'$ , would be  $23^{\circ}40'$ , agreeing with Diller's discovery.

**G3** Several scientists' (not historians') statistical studies of the Ancient Star Catalog, Hipparchos' *Commentary*, and Pliny's latitude data, all confirmed the same  $23^{\circ}2/3$  Hipparchan obliquity: Rawlins 1982C, Nadal & Brunet 1984, Rawlins 1985G, Rawlins 2009S fn 50. And *idem* Tables 1&2 (improved by melding them into Rawlins 2018C Table 1, or [www.dioi.org/biv.htm#lkhs](http://www.dioi.org/biv.htm#lkhs)) demonstrated that Diller's theory *perfectly satisfies all 14 Strabo-attested data, even ones Diller didn't know of*. Typically, historians-of-science shun him, preferring instead the failed joke-theories of their own people: Neugebauer 1975 (pp.304-6, 334-335, 734 n.14) whose paraplegic formula fit only c.1/2 Strabo's data; or least-squaresless Jones 2002E, whose theory fit *so poorly that he won't even tabulate it*. (And none among the JHAD-rabbitariate will even ask him to.) Unique: Diller, Neugebauer, & Rawlins all tabulate, to check how well their hypotheses fit the Hipparchan data. Despite the Aubrey Diller 1934 theory's obviously superior — indeed flawless — triumph: **in the eighty-three years since publication no historian-of-science has ever admitted it.**

## H Equinox or Solstice? Historians' Bad Science & Oblivious History

**H1** Too many of the most prominent historians (including a MacArthur recipient and the Editor of the *Journal for the History of Astronomy*) aver that ancients observed equinoxes more accurately than solstices, an elementary (R.Newton 1977 pp.81-82) confusion of precision with accuracy: actually believing that the Sun's lack of north-south motion at solstice prevents accurately measuring its time. (Swerdlow 1979 p.527, 2010 p.173, Evans 1998 p.206. Contra R.Newton 1991 fn 20 and Rawlins 2018U eqs.5&21, Table 3, §§D-J.)

**H2** Besides Swerdlow's and Evans' patent unfamiliarity with the relevant **SCIENCE** — the simple, well-known equal-altitudes technique (e.g., Bowditch *American Practical Navigator* 1981 ed. vol.2 p.799) — we note also their **HISTORICAL** innocence of the fact that all known ancient scientists found yearlengths via solstices, not equinoxes: Meton, Euktemon, Kallippos, Dionysios, Aristarchos, Hipparchos; and see *Astronomical Cuneiform Text* #210. Equal-altitudes (§H3 below) is the obvious ancient solstice-fix method. Recently, the details were fully laid out for the 1<sup>st</sup> time at Rawlins 2018U (eqs.5&10-21), plus invention of an equation for finding the method's modest systematic error (ordmag 1<sup>h</sup>) due to the Earth's orbital eccentricity (*ibid* eq.10). And those who've long doubted ancients' solstice-accuracy have lately been surprise-confronted with the freshly translated papyrus *P.Fouad* 267A, testifying to a Hipparchos  $-157/6/26$  18<sup>h</sup> solstice, **accurate to under an hour**. The papyrus also showed he was at this date tabulating Kallippic solar motion. **NB:** Hipparchos' [a] search for a  $-157$  solstice & [b] use of Kallippic motion, were both predicted years prior by Rawlins 1991W §§K8-K9&M4, from groundbreaking *DIO* analysis of Hipparchos' 2 eclipse trios. Neither [a] nor [b] were previously suspected by anyone. (See [www.dioi.org/vin.htm](http://www.dioi.org/vin.htm), for several dozen other equally undeniable *DIO* vindications.) *However, no JHA cultist will or can admit either of these 2 ineluctable predictive successes.* [Such behavior is the hallmark — the very definition — of shun-fear-driven robotic cultism.]

**H3** Equinoxes were observed on the large public equatorial ring in Alexandria. The sole surviving one, from  $-145/3/24$  11<sup>h</sup> (*Almagest* 3.1) was off by  $-4^h$ , but observer-errors were only c.1', considering all refraction (of Sun's light, plus polestars' light when the ring was originally set). Hipparchos' 14 Rhodos equinoxes show 2<sup>h</sup> or 2' scatter. Their systematic error was 7' (Britton 1967 p.24, R.Newton 1977 p.78, Rawlins 2018U §B4), all but ordmag 1' of which was from non-observational factors (*idem*), none degrading solstices found by equal-altitudes: measuring the LAN Sun's northness a few weeks before solstice, recording when it's repeated later, and simply taking the mid-time as solstice; these data's ere&aft systematic errors are of virtually equal size but opposite sign, and so cancel each other.

**H4** The accuracy (§H2) of papyrus *P.Fouad* 267A's  $-157$  solstice isn't isolated. Reconstructions of Aristarchos', Kallippos', & Hipparchos' solstices show errors of just 0<sup>h</sup>-3<sup>h</sup> (Rawlins 2018U Table 3), despite accuracy having been vitiated by the ancient habit of rounding cardinal-point times to the nearest quarter-day. (See *ibid* for full analysis.)

## I Eclipse-Fixed Stars: *Journal for the History of Astronomy* Miracles

**I1** The most prominent argument for alleged ancient empirical incompetence appeared 30<sup>y</sup> ago (Evans 1987, Evans 1998 p.259), citing 2 awful Hipparchan placements (*Almagest* 3.1) of Spica's ecliptical longitude by measuring its angular distance from the mid-eclipse Moon (virtually 180° from the Sun) during the eclipses of  $-145/4/21$  &  $-134/3/21$ . Errors were huge,  $-33'$  &  $+33'$ , respectively, thus double-backing the denigrators.

**I2** But, just to make sure, the author — today esteemed Editor of the "premier" & pseudo-refereed (Rawlins 2018C fn 4) *Journal for the History of Astronomy* — repeated the experiment himself, outdoors in Seattle, using the 1981/7/16 eclipse to place star  $\lambda$  Sgr with an antique cross-staff, finding that his longitudinal result was "too small by about 40'" (Evans 1987 p.275 n.50), convincingly in line with the size of Hipparchos' two gross errors.

**I3** But, wait a minute: all 3 errors are larger than the Moon! — whose mean diameter is merely 31', so *in none of the 3 cases did the reported lunar disk overlap or even touch the real one*. Is this credible? — given that the healthy human eye's discernment-limit is better than 1', & given that all Hipparchos' other lunar observations exhibit errors of merely 0°.1. (Thurston 1998A ☉11; Rawlins 2009E fn 22.) Can one believe an error exceeding the lunar diameter even once, much less thrice! So we have *three* miracles, felicitously just enough for Evans' official canonization to sainthood, according to longstanding Church practice.

**I4** A key proof, of 2<sup>nd</sup> century BC spherical trigonometry, is Hipparchos' use of lunar parallax tables — still surviving at *Almagest* 2.13. (A collection of prime evidences for spherical trigonometry's 2<sup>nd</sup> century BC currency is found at [www.dioi.org/cot.htm#mmsz](http://www.dioi.org/cot.htm#mmsz).) The Moon is the only natural celestial object that is (long-term) so close to the Earth that the naked eye can easily discern diurnal parallax, the difference between a topocentric position of the Moon seen outdoors from a site on the Earth's surface, vs a calculated geocentric position of the Moon as seen from Earth's center, the viewpoint of ancient and modern ephemerides. Parallax tables conveniently supply said difference so that an outdoor observation can be compared to a calculated geocentric position with parallax added.

**I5** But it is easy to instead subtract the tabular parallax by mistake. So, why not test that possibility upon the three observations adduced by our planet's brand-new §I3-saint? The needed data are easily acquired: Hipparchos would pre-calculate mid-eclipse-time from his lunisolar tables; and, by 1981, eclipse mid-time prediction was in the newspapers. Undoing all 3 wrong-signed parallaxes, the errors that were supposed to be  $-33'$ ,  $+33'$ , &  $-40'$  instead (Rawlins 2009E eqs.6-8 & fn 22) drop to, resp,  $-2'$ ,  $+1'$ , &  $+2'$ .

**I6** Well, does anyone seriously contend that human vision was 10 times worse 2000<sup>y</sup> ago than today? Though none of history-of-astronomy's networkers will ever confront their sly Leader, all who've checked the foregoing long-circulated shocker-facts realize that these have howitzered *JHA*'s pathetic pretensions to integrity & scientific knowledgeability, besides promoting false math in support of §A1's ultimate historical crime of cult-spurning, spitting-on, distorting — indeed *inverting* — THE central, overarching truth of ancient

astronomical history (*DIO* 1.1 ‡1 fn 24): **Greek scientists' high competence & accuracy.** (More seemingly incredible JHAD inversion-excesses are detailed at Rawlins 2018B §N.) *JHA* hopes *never* to admit *DIO*'s unanswerable success in neat-fit-explaining (§15) all three Evans 1987-selected hitherto-mysterious observations. Saint Evans intends to keep **HIDING** (*sneeeaky* details at www.dioi.org/jg01.pdf, §A1 & fn 7), fleeing exposure of what he hope-imagines (since colleagues stay silent) is his private guilty secret. Which isn't.

**I7** To comprehend the foregoing, recall Hume (*Enquiry Concerning Human Understanding* 10.2; 1740): "knavery and folly of men are such common phenomena, that I should rather believe [miracles] to arise from their concurrence than admit . . . a violation of the laws of nature." For St.Evans' 3 miracles, were the laws of human vision suspended? Or: are even saints — or more exalted yet, Editors — vulnerable to Humean-fallibility?

## J Distance to the Sun: the Origin of Order-of-Magnitude

**J1** At *Almajest* 5.15, nonastronomer Ptolemy put the Sun 1210<sup>f</sup> (Earth-radii) away, affecting 10<sup>f</sup> precision where uncertainty is way higher, as genuine ancient scientists knew. For real Greek scientists, solar distance (the AU) was so uncertain, it became the historical origin of order-of-magnitude as ancients resorted to rounding the AU to the nearest power of 10: Eratosthenes 100<sup>f</sup> (Rawlins 2008Q eq.11; Carman & St.Evans 2015, inflating a 6-line *DIO* footnote [Rawlins 2008Q fn 6; & eq.9] into a 16pp *Isis* Pb paper); Hipparchos 1000<sup>f</sup> (Rawlins 1991W eq.23); Aristarchos, Archimedes, & Poseidonios 10000<sup>f</sup> (*Sandreckoner* Archimedes, Heath 1913 p.348, Neugebauer 1975 p.656 eq.16, Rawlins 2008R eqs.13-15).

**J2** Aristarchos, a student of vision (Thomas 1939&41 vol.2 pp.2-3), presumably knew that the discernment limit of the human eye is ordmag 1/10000<sup>th</sup> of a radian; thus (Rawlins 1991W fn 272), diurnal parallax's invisibility, given a parallactic baseline of ordmag 1<sup>f</sup>, would've been convincing evidence — esp. at Mars stationary points — that the Sun's distance was at least 10000 Earth-radii, ordmagly-right (since the Sun is 23000<sup>f</sup> away).

## K Stellar Distances: Heliocentrist Trillionfold Universe-Expansion

**K1** One reason for geocentrists' resistance to Aristarchos' 3<sup>rd</sup> century BC announcement, that the Earth went around the Sun, was that it implied the stars would show annual parallax. **The before-the-nose fact that all the planets exhibited annual parallax had made no impression upon ancient geocentrists.** Or, indeed, upon modern historians-of-science — see Rawlins 1991P §F for an astonishing collection of naïve claims by prominent history-of-science archons that geocentricity-vs-heliocentricity remained an undetermined issue until the 19<sup>th</sup> century! The Church might relievedly agree: www.dioi.org/vols/w93.pdf, ‡6 fn 75. But J.Bradley's discovery of stellar aberration ended any reasonable scientific debate regarding geomobility, a century before infallible Holy Church quietly turncoated c.1835.

**K2** Aristarchos replied to §K1's doubters that stars' parallax was there, but was invisibly tiny from stars' huge remoteness, which, again applying vision's limit [with parallactic baseline ordmag 1 Astron Unit] must be at least 10000 AU distant, **an epochal discovery.** (Made by learning-from evidence, rather than cult-loyally rejecting it.) Multiplying this by §J2's parallel finding that the AU was at least 10000 Earth-radii: the stars must be at least 10000-squared or 100 million Earth-radii away. Given that annual-parallaxless Ptolemy's stellar distance was ordmag 10000 Earth-radii (Van Helden 1985 p.27 [vs *Almajest* 2.6]), the heliocentric universe's width was ordmag 10000 times greater than geocentrists', & volume greater by ordmag 1000000000000 — a trillion. **NB:** Connecting Aristarchos-Archimedes remotenesses — 10000<sup>f</sup> solar & 10000 AU stellar — to 1/10000<sup>th</sup>-radian eye-precision, is another original *DIO* discovery. (Ever uncited.) Why not previously perceived? Well — ever met a historian-of-science who knew the limit of human vision is c.1/10000 radians? For advancing history of science, knowing **science** matters. (As above at §H2 & ‡8 §D2.)

## L Doing Justice to Ancient Scientists

**L1** Historians-of-science treat Aristarchos, the scientist who pioneered heliocentrism and (§B) measured the month to 1 part in millions, as an incompetent fabricator (JHAD denigrations sampled at §A1 above and www.dioi.org/vols/we0.pdf, ‡2 §§A1, A3, & A6), which could be projection at its funniest. Prime basis for such is *On the Sizes and Distances of the Sun and Moon* — hitherto universally accepted as Aristarchos' — which makes the Sun&Moon 2° wide, thus implying wildly unreal events, like lunar eclipses lasting half a day (Neugebauer 1975 p.642), and even (Rawlins 2008R §§C1[e]&C3) **which no historian ever noticed: the Moon visibly retrograding every day for Mediterranean observers.**

**L2** But this allegedly-Aristarchan opus is contradicted by the greatest ancient mathematician-scientist: *Sandreckoner* reported (Archimedes p.223) that Aristarchos' lunisolar diameter was half a degree, which is correct and is 4 times smaller than *Sizes* claimed. What can explain the 4-factor descent into historians' abuse of Aristarchos? Well, try this theory: a hypothetical student of Aristarchos' work uncomprehendingly extrapolated from it, creating *Sizes* — where the lunisolar diameter is 1/15<sup>th</sup> of a **part** of the zodiac (Heath 1913 pp.352-353), thinking "part" meant a zodiacal sign, 30° wide. But the real Aristarchos he copied this datum from was referring instead to an ancient angular unit known as the "part" or meros (μερος), 1/48<sup>th</sup> of a circle, or 7°/2 (Neugebauer 1975 pp.652&671) — and 1/15<sup>th</sup> of that is a half-degree, in accord with both reality and Archimedes' testimony.

**L3** The myth of unempirical Greek science has endured for decades due to a confusion of ancient pseudo-science with the real thing, a confusion which began (ScAm 1979) as a means of ameliorating the error-enormity of Ptolemy's fabrications, by claiming that it was normal to preserve & report only data agreeing with prevailing theory. This is not only [a] logically impossible, for the self-evident reason given above (§A3), but [b] contrary to well-known ancient science, as Hipparchos reported data disagreeing with his theories & even with each other (*Almajest* 3.1, 4.11, 6.9), & [c] disproven by all sections of this paper.

**L4** The gulf between fake & real ancient science is typified by the following: the 4 allegedly outdoor "observations" of the Sun (*Almajest* 3.1&7) by history-of-science & AAS icon (and astrology-bible author) Ptolemy, "The Greatest Astronomer of Antiquity" (Neugebauer 1975 p.931, echoed verbatim by Gingerich 1976 p.477 & Gingerich 2002 p.70) are **50 times closer** to positions calculable *indoors* from Hipparchos' obsolete 280<sup>f</sup> old solar tables (*Almajest* 3.2&6) than they were to the Sun's actual positions in the real outdoor sky, so their errors average c.1° (the tables' mean error in 160 AD: Thurston 1998A ☉1), **twice the Sun's angular diameter.** Those historians who think this is science are less likely to look askance at the still-unretracted 1987 *Journal for the History of Astronomy* proposal (§I above) by *JHA*'s present Editor, that Hipparchos, a genuine outdoor observer, would commit equally outré ocular errors, **contra his customary accuracy** (§I3 above). Context: Hipparchos' Rhodos equinox observations are only 3 times closer to his tables (versus Ptolemy's 50), and even that only because, after all, the tables are computationally based (Neugebauer 1975 p.58) upon his slightly imperfect outdoor observations (as of 146 BC).

**L5** The astronomical and geographical errors of occultists have nothing to do with the brilliant work evaluated above, and should never be melded with it. One hopes that the foregoing survey's refinement-revelation of ancient science, shorn of superstition, will encourage future historians' realistic and grateful appreciation of ancient astronomy — man's 1<sup>st</sup> attainment of precise universal prediction, the heart of mathematical science.

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