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Eratosthenes' Lighthouse Ploy

EarthRadius 40800 Stades

Aristarchos' Vast Universe

Science's EoPrometheus

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News Notes

From the *International Herald Tribune* 2008/1/12-13 front-page obit for Edmund Hillary, 1953/5/29 co-conquerer of Mt.Everest: "In the annals of great heroic exploits, the conquest of Mt.Everest by Hillary[2] and [Tenzing] Norgay ranks with the first trek to the South Pole by Roald Amundsen in 1911 and the first solo nonstop trans-Atlantic flight by Charles Lindbergh in 1927." In the era B.D. (Before *DIO*) this would surely have read: Peary-N.Pole & Lindbergh-Atlantic. Popular history takes far too long to reach accurate equilibrium. And all-too-often never does. But we may savour justice when it comes.

[1] There is something hidden in this article. Onliners familiar with the Ptolemaic period's history will be most likely to spot it. The 1st person to do so & contact us receives a lifetime *DIO* subscription.

[2] When in 1999 the body of 1924 Everest-challenger George Mallory was found 2000 ft below the summit, the question arose: was he going up? — or coming down after attaining the top? Hillary answered that by opining that no conquest should count unless the conquerer returned to base. Hmmmm. And just where would that leave Brit ultra-polarhero Rob't Scott?

‡1 Eratosthenes' Too-Big Earth & Too-Tiny Universe

Pharos Reality Behind Alexandria-Aswan Myth
High-Precision Ancient Science Doubly Verified
Ultimate Geocentrist's Sun Smaller Than Earth

Dedicated to the Memory of
Our Irreplaceable Friend
HUGH THURSTON
1922/3/28-2006/10/29

A Big-Science's Dawn: Pharos as 1st Precise Earth-Measurer

A1 More than 22 centuries after Eratosthenes' legendary measure of the Earth, newly-mined ancient sources have finally permitted arrival at the non-astronomical truth behind the most famous of ancient geographical tales, the long-suspect myth of his 600-mile-travel to compare (§§A4[a]&D3) the Sun's noon altitude at Alexandria vs Aswan. The actual method instead used hometown measures of the height & night-visibility-distance of Alexandria's famous Lighthouse, which explains why the result was too high by a factor of 6/5 (eq.28), that being just the error (§B3) expected from air's bending of horizontal sealevel light.

A2 Rawlins 1982N (p.217 & n.26) discussed 2 easy stay-at-home methods which would account for the overlargeness of Eratosthenes' Earth-size, one being: measure how far over the sea a known-height lighthouse is visible at night. (Near-attestation at §A4[c].) But neither DR nor anyone else noted the coincidence that the tallest lighthouse in the world *debuted right at Eratosthenes' time&place, 3rd century BC Alexandria*? (§D5) — the "Pharos" (Greek for "lighthouse"), 2nd most durable of the ancient 7 Wonders of the World, surviving for 1 1/2 millennia. until ultimately falling to earthquakes and their aftershocks.

A3 With this glimmer of where we're headed, we now plunge into solving the entire Eratosthenes Earth-measure mystery: method, place, all his data (terrestrial and celestial), and we even develop (§I) the 1st credible (if quite speculative [at least until p.12's finale]) figure ever modernly proposed for the precise height of the Pharos itself. Further, we find (§F) that royals-catering Eratosthenes was a geocentrist who rejected obvious visual counter-indicia, to promulgate the anthrocentric delusion that the Earth is appreciably bigger than the Sun. Finally, it will be shown (§K2) that air-bending ("atmospheric refraction") of horizontal light explains ***both*** of the equally erroneous but extremely disparate (fn 8) ancient standard Earth-sizes (Eratosthenes & Poseidonios) within c.1% in each case (§K4).

A4 Before beginning, it's best to recall the four options available for ancient Earth-measurement, and each's respective atmospherically-induced error:
[a] Kleo Method: compare Summer-solstitial noon Sun's measured altitude at different latitudes. This is the still-famous and oft-repeated "Eratosthenes" method (Rawlins 1982G), given at Kleomedes 1.10 for Alexandria vs Aswan, which we will variously show (§D3, §G2, §H2, fn 7) is perfectly mythical. Negligible inherent error (§K2) for the cited cities.
[b] Mountain Method: measure the sea-horizon's angular "dip" (below 90° from zenith), as seen from a mountain peak of known height. (Rawlins 1982N App.A.) Error factor 6/5.
[c] Pharos Method: measure how far out to sea a lighthouse of known height is visible at sealevel. (*Ibid.*) Error factor 6/5. Like ancient-experimentation hint: Pliny 2.164.
[d] Sunset Method: measure difference in sea-horizon sunset-times for two known heights above sealevel. (*Ibid*, Rawlins 1979, & www.dioi.org/cot.htm#bsqq.) Error factor 5/6.
Summarizing the respective methods' errors: c.0%, +20%, +20%, −17%.
(All these errors would be appreciably weaker for great heights' thinner air: fn 1.)

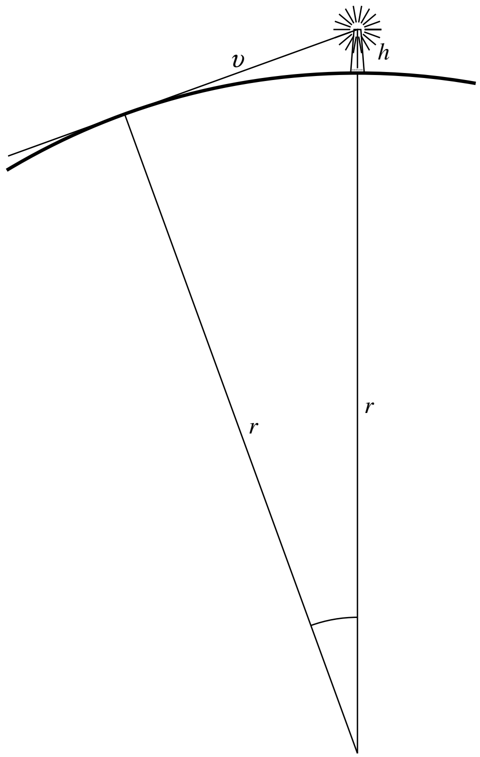

Figure 1: Pharos of height h, sealevel-visible at distance v, over Earth of radius r. (Height h [and thus v] is greatly exaggerated for illustrative clarity. Also: the actual Pharos was [according to coins] probably squatter than depicted here; and it was constructed in three sections — of diminishing breadth, as one ascended.)

B Lighthouse Math

B1 The math of the Pharos Method is so easy that it doesn't even require a diagram, though we supply Fig.1 anyway. At whatever distant point the Pharos' flame starts (due to Earth-curvature) becoming invisible to a receding observer on the sea, is where the Pharos' light-rays skim (are tangent to) the sea. Let v be this observer's distance from the Pharos, and r his distance from the Earth's center, while the Pharos' flame is $r + h$ from that center — h being the Pharos' height and r the ideally-spherical Earth's radius. At the observer's position, it is obvious that the angle between the skimming-light-ray vector and the Earth-radius vector is a right angle.

B2 Assuming an airless Earth (which permits straight-line light-rays), we can use Pythagoras' Theorem:

$$v^2 + r^2 = (r + h)^2 = r^2 + 2rh + h^2 \tag{1}$$

Cancelling r^2 from each side and dropping relatively trivial h^2, we have the naïve Airless Lighthouse Equation which ancients would have used to determine Earth-radius r:

$$r = v^2/2h \tag{2}$$

B3 But to find the *Real* Lighthouse Equation (based on Earth-with-atmosphere) at sealevel, one must account for horizontal atmospheric refraction, which stretches v artificially by the square root of 6/5 since horizontal light is bent with curvature equal to 1/6 of the Earth's curvature (S.Newcomb 1906 pp.198-203) so v^2 in eq.2 is augmented by factor 6/5, producing an Earth-radius high by 20%. (Curvature is defined as inverse of radius.) To return the problem to the straight-ray Pythagorean math behind eq.2 requires undoing the effect of the ray's curvature. Ancients may have suspected atmospheric refraction (‡2 fn 56), but no evidence for quantitative corrections exist until Tycho (c.1600 AD). Since the radius-estimate an ancient scientist would compute (via good Pharos-Method data) would be high by factor 1.2, the Real Lighthouse Equation is (using eq.2):

$$R = r/1.2 = v^2/2.4h \tag{3}$$

— from which one can get an accurate estimate of the Earth's real radius R instead of the 20%-exaggerated r one would get from the ancients' refraction-innocent eq.2.

B4 Rawlins 1979 applied very similar elementary straight-ray math & diagram to the §A4[d] Sunset Method of Earth-measure. (Though that method's resulting Earth-radius is low by factor 5/6, from air-refraction.) The pre-refraction-correction math of the §A4[b] Mountain Method (result high by 6/5, like the §A4[c] Pharos Method) is much the same.[1]

B5 Application of the Pharos Method would have been particularly simple because the shore along the Alexandria region is straight enough that one would not need to bother with ships: v could've been found by simply wheel-odometering the distance along the shore (checking by triangulation) until the Pharos light was no longer visible. The Pharos' height h was knowable via trig or by measuring ropes hung from flame, to successive sections, to sea; though, as suggested below (§I1), the exact height was probably already known.

B6 K.Pickering notes that on the nearly-linear coast just west of Alexandria, at distance c.20 nmi, the Pharos (slightly off said coast) is seen over the sea at azimuth c.40°. In this direction, the R corresponding to the sea's real curvature can be shown to be 6371 km = 3440 nautical (geographical) miles = 3959 statute mi ≐ 34400 stades, so we take this as the effective value of R in the discussions below, where we use the standard 185 m Greek stade (embedded in all our fits, which thereby confirm conventional opinion [§J1] on the stade).

C Pharos' Approximate Height

C1 Josephus *J.War* 4.613 says the flame of the Pharos was visible to ships for 300 stades (obviously a round figure for v), which would by eq.3 make it the world's then-tallest building (exceeding the Great Pyramid); yet it was never so described. Solution to Josephus' datum: the crow's-nests of tall ancient ships were roughly 1/4 of the Pharos' height, meaning (eq.3) that approximately 1/3 of Josephus' 300 stades was due to ship-height; so $v \approx$ 200 stades is an adequate rough estimate for the Pharos' visibility-distance v at sealevel.

[1] While seeking an explanation of Eratosthenes' result, DR has in recent years been inexplicably distracted by the §A4[b] Mountain Method. (Thurston 2002 p.66 evidenced better memory and sense.) Yet it is obviously inferior (to the §A4[c] Pharos Method): it involves measuring a small angle — and the 1% precision of agreement with Eratosthenes' actual Earth-radius would require 1′ measuring accuracy under difficult seeing conditions. (Also, the great height required to get an angle large enough to render observer-error negligible would lead to weakening of refraction due to decreased atmospheric density-gradient, yet the error in C_N is closely [§I3] consistent with virtually full-strength sealevel refraction.) Advantageously, the Pharos Method does not even get involved with angles at all, and the requisite relative precision is attained with ease. Note: the Mountain Method would lead to two-significant-digit results; the Pharos Method, three. So the very fact that Eratosthenes expressed his Earth-radius to three (eq.13) provides yet another indication that he used the Pharos Method.

C2 Thus eq.3 gives us a pretty good estimate of what was the Lighthouse's height h_{L}:

$$h_{\mathrm{L}} = v^2/2.4R \doteq 200^2/(2.4 \cdot 34400) \doteq 0.48 \text{ stade} \approx 1/2 \text{ stade} \approx 90m \qquad (4)$$

D Eusebios Bequeaths Us Eratosthenes' Exact Earth-Radius

D1 Eusebios, Bishop of Caesarea-Palestine, is most remembered for leaving us his invaluable *Ecclesiastical History* of the Christian church at its time of triumph.
D2 We will henceforth also owe him for the long cast-aside, here vindicated clue relayed in his *Præparatio Evangelica*, which unlocks the full truth behind the most enduring of ancient geographical legends, Eratosthenes' measurement of the Earth. The key data (Eusebios PE 15.53):[2] Eratosthenes had the Moon 780000 stades distant; and the Sun, 4080000 stades. We formally list these two Eratosthenes distances:

$$M_{\mathrm{E}} = 780000 \text{ stades} \qquad (5)$$

$$S_{\mathrm{E}} = 4080000 \text{ stades} \qquad (6)$$

D3 The traditional Eratosthenes Earth-circumference C_{K} is based upon the famous §A4[a] Kleo "experiment" (Kleomedes 1.10): Summer Solstice Apparent Noon Sun's zenith distance (90° minus altitude h) was 1/50 of a circle at Alexandria but null at Aswan-Elephantine (very near Tropic of Cancer) where legend had vertical sunshine reaching well-bottom: two cities 5000 stades apart in latitude. (Kleomedes 1.10 does not say that the 5000 stade distance was measured, merely calling it a "premis".) So:

$$C_{\mathrm{K}} = 50 \cdot 5000 \text{ stades} = 250000 \text{ stades} \qquad (7)$$

If one checks this vs the Bishop Eusebios-reported solar distance S_{E}, we find ratio p_{BK}:

$$p_{\mathrm{BK}} = 2\pi S_{\mathrm{E}}/C_{\mathrm{K}} \doteq 103 \qquad (8)$$

much too unround a number, given ancient convention (‡2 fn 37) of using powers of 10 for loosely-determined distances. (This habit is the earliest historical evidence for use of order-of-magnitude [ordmag] estimation of that which is too uncertain for more exact gauging. In this tradition, Poseidonios made the solar distance 10000 Earth-radii: ‡2 §F2 eq.15.) If we instead adopt the Eratosthenes circumference $C_{\mathrm{G}} = 252000$ stades (which he'd presumably [vs fn 6] adjusted slightly for geographical convenience to a round ratio of 700 stades per great circle degree: Strabo 2.5.7), a fresh check instead produces ratio p_{BG}:

$$p_{\mathrm{BG}} = 2\pi S_{\mathrm{E}}/C_{\mathrm{G}} \doteq 102 \qquad (9)$$

but this is also unacceptably non-round.
D4 However, years ago, DR analysed the Nile Map which Strabo 17.1.2 attributes to Eratosthenes, and showed (Rawlins 1982N p.212) that the underlying measure was

$$C_{\mathrm{N}} = 256000 \text{ stades} \qquad (10)$$

When we check this vs Eusebios' $S_{\mathrm{E}} = 4080000$ stades (eq.6), the Sun/Earth-radius ratio p_{BN} provides a pleasant shock, as we begin our realization that C_{N} unleashes the long-dormant Eusebios data-treasure of eqs.5&6:

$$p_{\mathrm{BN}} = 2\pi S_{\mathrm{E}}/C_{\mathrm{N}} \doteq 100.1 \qquad (11)$$

[2] See www.tertullian.org/fathers/eusebius_pe_15_book15.htm or H.Diels *Doxographi Graeci* Berlin 1879 pp.362-363. Eq.6's S_{E} is so startlingly small (entailing a Sun smaller than Earth: eq.16) that Heath 1913 p.340 just can't believe it. Such inertia has prevented entertainment of the hypothesis (§F3) that pol's-pol Eratosthenes found it advantageous (& healthy: ‡2 fn 69) to be a geocentrist's-geocentrist.

D5 ***This is a hit that carries us right into the heart of the Earth-measure mystery***. The obvious conclusion from eqs.6&11 is that Eratosthenes had the Sun's distance equal to 100 Earth-radii, so

$$S_{\mathrm{E}} = 100 r_{\mathrm{E}} \qquad (12)$$

$$r_{\mathrm{E}} = 40800 \text{ stades} \qquad (13)$$

the only 3-significant-digit Eratosthenes figure for the Earth's size directly based on empirical data. (Compare eq.13 to eq.7.) *All pre-Pharos C were 1-significant-digit-rough*: 400000 stades (Aristotle c.350 BC), 300000 stades (Dikaearchos c.300 BC). Yet (§I1) after the Pharos' debut, we find ordmag 100 times greater precision in 3-significant-digit eq.13.

E Eratosthenes' Moon

E1 While placing the Sun 100 Earth-radii distant, far short of Aristarchos' solar distance, Eratosthenes nonetheless adopted the farcical lunar distance of pseudo-Aristarchos,[3] 19 Earth-radii (Heath 1913 pp.339 & 350; but see ‡2 §C5), as eq.13 verifies:

$$M_{\mathrm{E}} = 19 r_{\mathrm{E}} = 775200 \text{ stades} \doteq 780000 \text{ stades} \qquad (14)$$

which matches[4] eq.5, Eusebios' report. (The match is far better than that figured at Heath 1913 p.340, where $2\pi/19$ is divided into the hitherto-conventional Eratosthenes $C = 252000$ stades, yielding about 760000 stades.)
E2 But if we try recovering the lunar distance from the Nile Map C_{N} (eq.10):

$$19 C_{\mathrm{N}}/2\pi = 774130 \text{ stades} \doteq 770000 \text{ stades} \qquad (15)$$

we find that it does not check with eq.5.
E3 Comparison of eq.15 to eq.14 begins a linchpin realization: *Eratosthenes' root measurement was Earth-**radius**, not Earth-**circumference***. The historical import of this revelation will become evident below (§G2).

F Eratosthenes' Sun

F1 Remarkably, Eratosthenes had the Moon's distance almost 1/5 of the Sun's — which goes counter to easy visual checks, since if his 19:100 ratio were true, half-Moons would occur with the Moon more than 10° from quadrature. (Arcsin 0.19 $\doteq$ 11°.)

[3] DR has long contended (‡2 §C1 etc) that Aristarchos' supposed ms "On the Sizes and Distances of the Sun & Moon" is not truly his but is by an uncomprehending pedant (follower, detractor, distractor?), since the work is vitiated by an error of *a factor of four* (mis-step's amateurish origin explained at ‡2 §C1), leading to a 2°-wide Moon and thus (‡2 §C5) a 4° wide Earth-shadow at the Moon, which would imply central lunar eclipses' Entirety (partiality-start to partiality-end) lasting *half a day*, with c.4^{h} Totality (durations too high by factors of about 3 and 2, respectively), as well as requiring the Moon to visibly retrograde daily! — this joke-astronomy having become the royally approved lunar theory in the Alexandria that elevated Eratosthenes to top academic. (Full incredible details below at ‡2 §C.) Eratosthenes' adoption of this way-too-low lunar distance (vs DR's reconstruction of c.60 Earth-radii for Aristarchos: ‡2 §C11) suggests that the acceptance of pseudo-Aristarchos' work as genuinely Aristarchos' goes way back. (It also suggests little comprehension by Eratosthenes of his lunar distance's two most ludicrous implications, as just remarked. Perhaps lunar parallax was not recognized by some scholars of the 3rd century BC, though it is obvious that Hipparchos had parallax tables only a century later: Rawlins 1991W fn 288.) Note that, by contrast with Eratosthenes (and modern scholars), Archimedes didn't fall for any of pseudo-Aristarchos' bizarre astronomy: ‡2 fn 33.

[4] A lunar distance of 19^{e} implies 3° Earth semi-diameter as seen from the Moon, which itself was anciently gauged as having semi-diameter 1°/4 as seen from the Earth; that is, seen at the same distance, the Moon has merely 1/12 the Earth's angular sd. Thus (by the same symmetry argument we'll use at §F3), the Moon's radius is 1/12 the Earth's so (in adopting pseudo-Aristarchos' lunar distance of 19 Earth-radii: ‡2 §C5) Eratosthenes had the Earth's volume about $12^3 \approx 1700$ of the Moon's!

F2 This bizarrity seems less likely to be the result of observation than of patch-work synthesis: melding two distances from two distinct sources, regardless of compatibility. A possible trigger: the Sun's size shrank for ascientific reasons (royally-oily Eratosthenes was a fave of the Ptolemies' theocratic Serapic regime: Rawlins 1982G p.265), the Sun's greater size having been a likely spark to the proscribed heliocentrist heresy.
F3 From Eratosthenes' 100 Earth-radii solar distance (eq.12), we see that the Earth's angular semi-diameter as seen from the Sun would be $180°/100\pi = 0°.573$, while the semi-diameter of the Sun (seen from the same 100 Earth-radii distance) was pretty accurately estimated (‡2 §C1) to be $0°.25$. Therefore, the implicit solar size s in Earth-volumes is:

$$s = (0°.25/0°.573)^3 \doteq 1/12 \tag{16}$$

So Eratosthenes was pretending that the Sun was 12 times smaller than the Earth![5] Such cosmology doubtless delighted (and offered justifying comfort to) gov't-catering geocentrist priests, whose anti-progressive view of the universe dominated the world by force for millennia, until modern times. This discovery widens our basis for appreciating how Eratosthenes climbed to academic eminence in Ptolemaic Alexandria, promoting a cozy universe trillions of times smaller than that already proposed by Aristarchos of Samos. (Note ‡2 fn 33 & §H1.)

G Eratosthenes' Earth

G1 The Nile Map's Earth-size is now confirmed by congruence (eqs.5-14) with Eusebios' numbers, so we ask how well the map's underlying $C_{\rm N}$ (eq.10) generates the radius:

$$C_{\rm N}/2\pi = 256000/2\pi \doteq 40700 \text{ stades} \neq r_{\rm E} \tag{17}$$

— no match. But the reverse process does create a match to eq.10. Starting from eq.13:

$$2\pi r_{\rm E} = 2\pi \cdot 40800 \text{ stades} \doteq 256000 \text{ stades} = C_{\rm N} \tag{18}$$

This contrast (eq.17 vs eq.18) confirms the §E3 finding, so that we now have double-evidence that Eratosthenes' *radius generated the circumference* $C_{\rm N}$, not the reverse.
G2 What is the significance of this priority? Simple: it kills the legend that Eratosthenes got the size of the Earth by the famous Kleo Method (based on measuring the distance from Alexandria to Aswan: §A4[a]), because that method's math (eq.7) *produces circumference*. By contrast, the Pharos Method (§A4[c]) directly *yields the Earth's radius*: eq.2. Thus, the clear implication of the radius' computational priority is that the Pharos Method (not the Kleo Method) was that actually used by Eratosthenes or his source to find the Earth's size. (The Kleo Method's untenability will be independently confirmed below: §K2 & fn 7.)

H Inventing the "Experiment"

H1 As noted at Rawlins 1982N n.10, Eratosthenes was possibly unsure of whether the Mediterranean Sea's curvature matched the world's. If so then (*ibid* p.216) he may have unwittingly based his 5000 stade supposed-meridian (Alexandria-to-Aswan) & his $C_{\rm K}$ ultimately upon use by another scholar (see, e.g, §I1) of the very method he questioned. It is also possible that he knew where the basic measurement came from and himself concocted the famous "experiment" as a useful illustration even though it was actually founded upon a rounding of $C_{\rm N}$ (eq.10), as titularly noted by Rawlins 1982N — and while doing so found that a round distance of 5000 stades would nearly dovetail $r_{\rm E}$ with his (defective: Rawlins 1982G n.19) gnomon observation of the solstitial Sun's culmination zenith distance, $7°12'1/2$ (*ibid* n.20 & Table 3), the rounding of which to $7°1/5 = 360°/50$ became the purported basis of his ultimately canonical $C_{\rm K} = 250000$ stades.[6]
H2 Whatever the exact descent to $C_{\rm K}$, the conclusion here is that the famous Alexandria-Aswan "experiment" was a textbook-style construct based upon the real prior experiment, which was enormously simpler physically — namely, using the nearby Pharos. That is, instead of walking 5000 stades or 500 nautical miles (nmi), the measurer walked merely (eq.4) c.200 stades or 20 nmi. His result was high because of atmospheric refraction. Had he known of (corrective) eq.3, he would have found

$$R = r_{\rm E}/1.2 = 40800 \text{ stades}/1.2 = 34000 \text{ stades} \tag{19}$$

close to the truth (§B6), 34400 stades. For naïve eq.2, perfect data would've given (§B3)

$$r = 1.2 \cdot 34400 \text{ stades} \doteq 41300 \text{ stades} \tag{20}$$

The discrepancy with eq.13 is merely 1%, on the order of naturally occurring variations in eq.20's 1.2 factor. So the ancient mystery of Eratosthenes' measurement has a solution.

I Pharos' True Height: Was 40800 Stades *Sostratos*' Earth-Radius?

I1 We next launch a speculative attempt at finding the Pharos' exact h. (The following reconstruction of precise v originated subsequent to §C's rough estimate of it.)
The Pharos was a pioneering, literally-superlative civic-science project. So: was its height h a proud world-lighthouse-record round number of Greek feet? (Greek foot $\doteq 12''1/7$ English.) We already have evidence (§C2) that h equalled about a half-stade, so was the Lighthouse deliberately constructed to be 300 Greek feet high, the flame *exactly* (vs eq.4's roughly) 1/2 stade above sealevel, making eq.2's denominator equal 1 stade?

$$h_{\rm L} = 1/2 \text{ stade} \qquad \text{thus (in stades):} \quad r = v^2 \tag{21}$$

So anyone could find the Earth's radius r in stades, just by pacing v in stades and squaring it. The big metal ring in Alexandria's Square Stoa was an equinox-detector (*Alm* 3.1), so could the sailor-beacon Pharos have doubled as a huge Earth-measure science experiment (as the Empire State Building originally doubled as a dirigible-dock)? Was such a neat idea planned (c.270 BC, the Museum's apogee: ‡2 fn 33) by Pharos-builder Sostratos & fellow scientists, who thus may (§A2) have established $r = 40800$ stades (eq.24) before Eratosthenes? Our speculation isn't disconfirmed if 40800 turns out to be near the square of a 3-digit integral v: there is only a 25% *a priori* probability that the 1/2-stade-Pharos-height theory will meet this condition. (If Eratosthenes' $r_{\rm E}$ had equalled, say, 40600 or 40700 or 40900 stades, our eq.21 speculation would be eliminated.) But if we root $r_{\rm E}$, we find

$$\sqrt{40800} = 201.99 \tag{22}$$

[5] Note Sun-shrinker Eratosthenes' Scylla-Charybdis narrows: bringing the Sun near enough to make it smaller than Earth, while putting the Moon not too close to the Sun (thereby inflating ‡2 eq.4's γ) but not too close to the Earth, since that would entail huge daily lunar parallactic retrogrades.
(A contended Macrobius passage has Eratosthenes' Sun 27 times Earth's size: I.Kidd 1988 p.454. Did Macrobius invert the ratio? If the math of §F3 used smaller solar sd (Heath 1913 p.312-314), perhaps also rounding π to 3, then the computed Earth/Sun radii-ratio could be ≈ 3, the cube of which is 27.)

[6] Once the 5000 stades baseline led (eq.7) to $C_{\rm K} = 250000$ stades, it is possible that the question of parallax was raised. Parallax correction for an Alexandria S.Solstice culminating Sun at $100r$ would shave 1% off the zenith distance and thus add 1% to the circumference, yielding c.252500 stades or (rounding low) 252000 stades (700 stades/degree) which offers an alternate explanation (vs §D3) for the origin of that famous value. If $7°12'1/2$ was not rounded to $7°1/5$, then $C =$ (5000 stades)$\cdot 360°/7°12'1/2 = 249711$ stades. Adding 1% yields 252208 stades $\doteq$ 252000 stades.

I.e., the 1/2-stade-high-Pharos theory survives. So, using it, we'll compute out a determination of r on the assumption that Eratosthenes' measured (§B5) sealevel Pharos-visibility distance v was

$$v = 202 \text{ stades} \quad (23)$$

(Not far from the crude §C1 estimate used in eq.4.)

I2 When these values are substituted into eq.2 (or eq.21), the result is:

$$r_{\mathrm{E}} = v^2/2h = (202 \text{ stades})^2/(2 \cdot 1/2 \text{ stades}) = 40804 \text{ stades} \doteq 40800 \text{ stades} \quad (24)$$

which neatly matches Eratosthenes' radius (eq.13).

I3 As an illustration of the accuracy of the work behind Eratosthenes' value, we check via eq.3, using the real Earth-radius $R = 34400$ stades of §B6, and (somewhat over-ideally taking the equation's 1.2 factor as exact) find that a perfect Pharos Experiment for a 1/2-stade Lighthouse would have measured $v = 203$ stades. Not only does this (compared to eq.23) evidence the care of the Greek scientists who performed the necessary measurements, but it also reminds us that (because v is squared in eqs.2&3) the relative error in the ancient experimenters' resultant r is about double that of v, so that their finding an Earth-radius 19% high (vs 20% high expected) shows experimental error of not 1% but roughly half that. N.B.: This point is independent of the 1/2-stade Pharos theory, and applies also to the Sunset Method (§A4[d]), whose resulting C_{P} (eqs.26&28) also depends upon the square of the crucial measurement. (Inverse-square of time-interval between sunsets in that instance. See Rawlins 1979.) In any case, since the 1.2 factor is not rigidly precise, the proper conclusion is that the two widely adopted ancient Earth-measures, Eratosthenes' ($r_{\mathrm{E}} =$ 40800 stades: eq.13) and Poseidonios' ($C_{\mathrm{P}} = 180000$ stades: eq.26), are so close (eq.28) to the values expected from the Pharos and Sunset experiments, respectively, that we can regard both tiny discrepancies as *within experimental noise* (§H2).

I4 So the matches for both famous ancient Earth-size values provide as precise a validation as one could reasonably require, for the sea-horizon-refraction theory of the values' origins. They are thus a spectacular refutation of & rebuke to the ubiquitous modern cult that has misled generations of young scholars into accepting the fantasy that ancient science was unempirical: see, e.g., ‡2 §§A1, A6, B3, & *especially* the priceless gem at ‡2 fn 20.

J Playing-Accordion with the Stade

J1 There has been a long tradition of attempting to force agreement of the Eratosthenes and Poseidonios values with each other and with reality by arguing for whatever stade-size would make-E&P-right. But it is encouraging to report that this sort of manipulation is no longer taken seriously by most specialists. (Such scholars as Dicks, Neugebauer, Berggren, and Jones have never fallen for it.) Amusing details of testimony-twisting (used to carry out such programmes) are exposed at Rawlins 1982N App.B and Rawlins 1996C fn 47.

J2 Eqs.24-28's matches gut not only the credibility of stade-juggling-for-Eratosthenes but even the very *need* for it. (See ‡3 fn 13.) We next adduce independent support for this conclusion.

J3 Lack of serious instability in the Hellenistic stade is also detectable from Ptolemy's geographical evolution. In the 18th century, Pascal Gossellin 1790 noted that the macro-geographical longitude errors of Ptolemy's *Geography* (*GD*) showed exaggerations of 30%-40%. Rawlins 1985G p.264 used least-squares analyses to find the mean exaggeration (factor 1.36 ± 0.04) and explained this as the result of switching Earth-sizes.

J4 In the *Almajest* Ptolemy was under Hipparchos' influence, so he presumably adopted his C which was (Strabo 2.5.34) Eratosthenes' C_{G} (§D3). When Ptolemy switched (‡3 fn 13 & §L3) to C_{P} (eq.26) for his later *GD*, he obviously used travellers' east-west distance-estimates more than astronomically based longitudes and so (in order to switch his great-circle scale from 700 stades/degree to 500 stades/degree) had to stretch degree-longitude-differences between cities. So the *Almajest* longitude-degree distance from Rome to Babylon was increased by over 30% (‡3 fn 13), nearly the ratio of the prime Earth-sizes, plain evidence that the stade was a constant in the midst of geographical transformation.

K How Atmospheric Refraction Fruitfully Explains *BOTH* Standard Ancient Earth-Size Estimates' Precise Errors

K1 As noted at §A4 & §B4, atmospheric refraction makes the §A4[d] Sunset Method of Earth-measure (Rawlins 1979) give a result low by factor 5/6. Since the actual circumference of the Earth is virtually by definition 21600 nautical miles (a nmi is now defined as exactly 1852m, nearly identical to $1'$ of great-circle measure on the Earth's globe), then given that a stade (185m) is almost exactly 1/10 of a nmi, we know the Earth's real circumference is:

$$C_{\mathrm{o}} = 216000 \text{ stades} \quad (25)$$

(600 stades/degree). The Poseidonios value (Strabo 2.2.2) of the Earth's circumference (which could appear only after the 2nd century BC advent of sph trig: Rawlins 1979) was

$$C_{\mathrm{P}} = 180000 \text{ stades} \quad (26)$$

(500 stades/degree), which agrees exactly with the §A4[d]-predicted Sunset Method's -17% error; and we have doubly found (eqs.10&18) Eratosthenes' empirical circumference

$$C_{\mathrm{N}} = 256000 \text{ stades} \quad (27)$$

(711.11 stades/degree), the $+19$% error of which is almost perfectly consistent with the §A4[c]-predicted Pharos Method's $+20$% error.

K2 While the Kleo Method (eq.7) should lead to a nearly correct circumference-estimate (for the method's near-zenith solar altitudes, refraction would be trivial), the two actual standard ancient values for the Earth's circumference are 6/5 high and 5/6 low, thus eliminating the Kleo Method right off the top — which backs up[7] our earlier elimination of it through a different approach (§G2). When we check ratios of theory and testimony, we find virtually exact hits on the horizonal-light-ray atmospheric-refraction hypothesis' 6/5 factor, for the sources of *both* attested standard C:

$$C_{\mathrm{N}}/C_{\mathrm{o}} = 256000/216000 = 5.93/5 \qquad C_{\mathrm{o}}/C_{\mathrm{P}} = 216000/180000 = 6.00/5 \quad (28)$$

which shows how dramatically successful the refraction theory has proven[8] — an ideal example of a fruitful theory, it uses the *same* mechanism (horizontal atmospheric refraction) and the *same* stade (standard 185m) to near-perfectly explain ***both*** of the only two widely adopted ancient Earth-size estimates. (N.B.: Rawlins 1996C fn 47.) Note that the spat which *must* have attended ancients' huge shift from C_{G} to C_{P} is unattested.

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[7] Other difficulties in arguing for the Kleo Method's reality: Eratosthenes placed (Kleomedes 1.10) Aswan due south of Alexandria (see also Rawlins 1982N), though an actual traveler from Alexandria to Aswan could hardly fail to notice that he was steering 20° east of south to go straight to Aswan. There is also the question of how one would measure the length of a path which could not have been direct without highly arduous and dangerous travel over desert, since the Nile is far from straight. Finally, there is the fact that if the Kleo Method were actually carried out (across awful Egyptian terrain) over a north-south straight line, it would get an accurate result. (More than 1000^y later the experiment was actually done [elsewhere], and the result was indeed accurate.)

[8] For those who cannot immediately see why the two methods yield such different results (one over 40% higher than the other!): see *DIO 2.3* ‡8 §A, where extreme examples easily illustrate why one method leads to a too-high result and the other to a too-low result. (The Mountain Method is examined there instead of the Pharos Method, but the atmosphere's effect on each is similar for low mt-height.) That is, if Earth's sealevel atmosphere-density gradient were high enough, the Pharos-light-rays' curvature could be the same as Earth's, so (for null extinction) the Pharos would be visible no matter how far away one receded, & this infinite v would (by eq.2) make computed $r = \infty$: a flat Earth. For the same dense atmosphere, the Sunset Method would yield $r = 0$ (*DIO loc cit*).

K3 But given the cascade of startling new matches above [& at this page's end], little doubt can remain that the ***unattested*** Pharos & Sunset Methods underlay the only 2 standard ancient Earth-sizes, C_G & C_P, resp. Which tells us what has often been shown in these pages (see, e.g., fn 9, ‡2 fn 38, ‡3 §A3): much of high ancient science has been lost & so is *only recoverable by reconstruction*, a finding unsurprising to most of us, yet which nonetheless eludes induction-challenged chauvinists who whenever convenient will (*DIO 11.1* p.3 & ‡2 fn 7) pretend that they cannot accept anything without extant textual explanation.

K4 But even more important than such details is the implicit general message contained in the foregoing precise vindication of the atmospheric theory that coherently explains the 2 ancient Earth-measures: the fact that both agree with the theory *to one percent* (§I3 & eq.28) overturns[9] the long-persistent delusion (§I4; ‡2 §A1, fnn 20&31) that the Greeks were mere theorists with little interest in or capacity for empirical science. *DIO* has been contending otherwise since its 1991 inception, arguing that this "blanket libel of ancient scientists" (*DIO 1.1* ‡1 fn 24) is false — and obviously so, to those possessing a genuine acquaintance with the way scientists think and work. We hope that the present paper will help diffuse a more appreciative view of the priorities, ingenuity, and perfectionism of those ancient Greek pioneers who laid the baserock-beginnings of high-precision science.

References

Almajest. Compiled Ptolemy c.160 AD. Eds: Manitius 1912-3; Toomer 1984.
Eusebios PE. *Præparatio Evangelica* c.310 AD. Ed: E.Gifford 1903.
Pascal Gossellin 1790. *Géographie des Grecs Analysée* . . . , Paris.
Thos.Heath 1913. *Aristarchus of Samos*, Oxford U.
Josephus. *Jewish War* c.79 AD. Ed: H.Thackeray, LCL 1927-8.
Ian G. Kidd 1988. *Posidonius: the Commentary*, Cambridge U.
Kleomedes. *Motu circulari* c.370 AD. Ed: H.Ziegler, Leipzig 1891.
Karl Manitius 1912-3, Ed. *Handbuch der Astronomie* [*Almajest*], Leipzig.
S.Newcomb 1906. *Compendium of Spherical Astronomy*, NYC.
Pliny the Elder. *Natural History* 77 AD. Ed: H.Rackham, LCL 1938-62.
D.Rawlins 1979. American Journal of Physics *47*:126.
D.Rawlins 1982G. Isis *73*:259.
D.Rawlins 1982N. ArchiveHistExactSci *26*:211.
D.Rawlins 1985G. Vistas in Astronomy *28*:255.
D.Rawlins 1991W. DIO-J.HA *1.2-3* ‡9.
D.Rawlins 1996C. DIO-J.HA *6.1* ‡1.
Strabo. *Geography* c.20 AD. Ed: Horace Jones, LCL 1917-1932.
Hugh Thurston 2002. Isis *93.1*:58.
Gerald Toomer 1984, Ed. *Ptolemy's Almagest*, NYC.

InductionQuake AfterShock

This paper was 1st posted and referees alerted on 2008/3/12. But on 2008/3/15, DR happened upon the obscure sole extant ancient estimate of the Pharos' height h: 306 fathoms (Steph.Byz 735a [1825 ed. 3:1251]; Strabo [H.Jones] 8:24n), taller than any building ever. Unless Greek feet were meant. If so, h is within 2% of our eq.21, and $v = 204$ stades. But it's suggestive that 306 & 40800 are both unround by factor 1.02. Did a later scholar try estimating h by putting $r_G =$ (252000 stades)/$2\pi \doteq 40000$ stades (Neugebauer 1975 p.654) and $v = 202$ stades (eq.23) into eq.2 to find $h \doteq 0.51$ stades = 306 ft? Regardless, after years of exaggerations, we now have double evidence for a conservative estimate:

$$\text{Pharos' height } h = 93\text{m} \pm 1\text{m}.$$

[9] Such achievements as eclipse-cycle determination (‡2 §F9) of all three of the Greek lunar periods (to a precision of one part in ordmag at least a million) might've triggered parallel enlightenment.

‡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[3] of) this same vast heliocentric worldview (§F2).

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 (pp.643) presumes that all the work attributed to Aristarchos has "little to do with practical astronomy". The famous "Aristarchos Experiment" based its ratio of the distances of the Sun&Moon upon the half-Moon's occurring 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] 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 observations.

[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 6.1* ‡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

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[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 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 6.1* ‡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 the time of each of these 2 solstices (*DIO 1.1* ‡6 §A5) 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: $1^d/4$.) 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.222). The point is regarded as too obvious for elaboration by, e.g., van der Waerden 1963 (p.203). (By contrast, Neugebauer 1975 p.643 says that the 10000 AU radius Aristarchan universe reported by Archimedes p.232 has "as little to do with practical astronomy" as Aristarchos' Experiment: eq. 4.[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 & 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 the Muffia's brass in upside-down historical-revision-apologia exceeds even the master's.)

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 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.

[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. And 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).

[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.]

[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 (which is consistent with the size of an Airy disk due to diffraction) for a pupil of human diameter. All these estimates flutter around μ = 1/10000 of a radian, the value found here to underlie all Aristarchan measures of the universe. See §B2.

[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.222 & 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 — without but 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",

[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 20th 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.

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 1/15th of a zodiacal sign or 2° wide in angular diameter (nearly 4 times the correct value), thus pseudo-A's semi-diameter was:

$$\theta_{\rm P} = 1^\circ \tag{2}$$

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

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

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°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°/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.

[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°/2 (solar diameter), 3° (half-Moon vs quadrature), & 10°2/3 or 32°/3 (saros remainder: Rawlins 2002A eq.6).

[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, the Moon is seen in its rising aspect (obvious to an outdoor astronomer) low behind the Sphinx, which is looking at the camera. 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) $r_\mathrm{M} = 20^\mathrm{e}.10$ (where 1^e = 1 Earth-radius). But it is well-known that the Moon's sidereal period is & was $27^\mathrm{d}.32$ (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

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

was an upper bound, not a precise figure. (The notation: r_M = the Moon's distance, and r_S = the Sun's distance.) Even allowing this,[32] Rawlins 1991W fn 272 showed that as merely 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 Eusebios (‡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:

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

using pseudo-A's false data (§C8 & eq.2): shadow-Moon ratio $\upsilon_\mathrm{p} = 2$ and solar semi-diameter $\theta_\mathrm{p} = 1^\circ$. 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?

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 $r_\mathrm{S} \approx \infty$ ($\gamma \doteq 0^\circ$). In that case, eq.5 becomes:

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

(More efficiently: $r_\mathrm{M} \doteq 60/\pi \doteq 19.1$.) So, Eusebios' verification that a lunar distance of 19^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.

[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 $20^\mathrm{e}.10$, 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 $19^\mathrm{e}.1$ 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^e (not 20^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_M. Yet another reason for the incredibility of the wildly false values for r_M entailed by pseudo-Aristarchos. Without, that is, both the emendations here suggested (in 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 $\gamma_\mathrm{A} = 3^\circ$ 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 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^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_S: 10000^e vs 360^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^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 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: 2° lunisolar diameter θ_P), we examine 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:

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

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

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

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:

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

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

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

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 $\gamma_\mathrm{A} = 3°$ (eq.4) or $\gamma_\mathrm{A} = 0°$ (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:

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

[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 $\theta_\mathrm{P} = 1°$.)

[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.

(Due to the obvious uncertainty in γ, this result could justifiably be rounded[37] to 1000^{e}.) Such a step could have triggered the later tradition — discovered at 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

[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!

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,

$$r_s = r_S/\mu = 10000 \cdot r_S = 10000 \text{ AU} \qquad (13)$$

This result is 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 the

[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, 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.

nearer star of Giedi were, say, 1000 AU distant and the other was 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 2·3438′/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) entails 7′ of ecliptical parallax — roughly twice as large as 3′.7 — which thus predicts the amazing spectacle of these two stars (α^1 Cap & α^2 Cap) seeming to pass each other back and forth annually! Obviously, no such effect was observed — and careful ocular monitoring of Giedi and similar star-pairs would produce 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.150 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 The "Sand-Reckoner" (Archimedes p.222, Neugebauer 1975 p.646 eq.11) contains an apparent suggestion that Aristarchos, at some point (possibly late) in his career, promoted a provocative symmetry of limiting distances (with R_{T} = Earth's radius):

$$r_{\mathrm{a}}/r_{\mathrm{S}} = r_{\mathrm{S}}/R_{\mathrm{T}} = 10000 \qquad (14)$$

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:

$$r_{\mathrm{S}} = 10000^{\mathrm{e}} \qquad (15)$$

[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 remarks that Pliny & churchmen "grumbled" about the nonutility of seeking the universe's scale.

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

[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 not chance?), had they (perhaps suspecting refraction) averaged standard Cs, 252000 stades & 180000 stades: ‡1 §§D3&I3?

[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°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 1146ᵉ (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 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 they disapprove. 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

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[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, 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.

[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

[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 *DIO* readers know, 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 1998 §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 $(10000/1000)\cdot(10000/10) \approx 10000$.

[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

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 forseeable future, intelligent scholars must see past (& calibrate for) the warps created by dim brains struggling in our current grant-hustling era, when [a] business priorities swamp concern for truth, and [b] businessman-scholars' intellectual dullness establishes the pathetic limit of (public) scholarly 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 such 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 professionalism & 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 papers in *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.

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*.

References

Almajest. Compiled Ptolemy c.160 AD. Eds: Manitius 1912-3; Toomer 1984.
Archimedes. *Works* c.260 BC. Ed: T.Heath, Cambridge U. 1897&1912.
B&J = J.L.Berggren & N.Sidori 2007. ArchiveHistExactSci *61*:213.
A.Dambis & Y.Efremov. JHA *31*:115.
J.Delambre 1817. *Histoire de l'Astronomie Ancienne*, Paris.
J.Evans 1992. JHA *23*:64.
J.Evans 1998. *History & Practice of Ancient Astronomy*, Oxford U.
O.Gingerich 1976. Science *193*:476.
O.Gingerich 1985A. JHA *16*:37.
O.Gingerich 1992K. Scientific American *267.5*:100.
O.Gingerich 1996. JHA *27.3*:277. Review of Thurston 1994E.
O.Gingerich 2002. Isis *93.1*:70.
B.Goldstein 1967. *Arabic Version of Ptolemy's PlanHyp*, AmPhilosSocTrans *57*.4.
Gerd Graßhoff 1990. *History of Ptolemy's Star Catalogue*, NYC.
W.Hartner 1980. ArchivesIntHistSci *30*:5.
Thos.Heath 1913. *Aristarchus of Samos*, Oxford U.
Hipparchos. *Commentary on Aratos & Eudoxos* c.130 BC. Ed: Manitius, Leipzig 1894.
Ian G. Kidd 1988. *Posidonius: the Commentary*, Cambridge U.
Kleomedes. *Motu circulari* c.370 AD. Ed: H.Ziegler, Leipzig 1891.
Karl Manitius 1912-3, Ed. *Handbuch der Astronomie* [*Almajest*], Leipzig.
O.Neugebauer 1955. *Astronomical Cuneiform Texts*, London.
O.Neugebauer 1957. *Exact Sciences in Antiquity*, 2^{nd} ed, Brown U.
O.Neugebauer 1975. *History of Ancient Mathematical Astronomy* (*HAMA*), NYC.
R.Newton 1973-4. QJRAS *14*:367, *15*:7, 107.
R.Newton 1977. *Crime of Claudius Ptolemy*, Johns Hopkins U.
Planetary Hypotheses. Comp. Ptolemy c.170 AD. Eds: Heiberg 1907; Goldstein 1967.
D.Rawlins 1982G. Isis *73*:259.
D.Rawlins 1982N. ArchiveHistExactSci *26*:211.
D.Rawlins 1984A. Queen's Quarterly *91*:969.
D.Rawlins 1985G. Vistas in Astronomy *28*:255.
D.Rawlins 1985K. BullAmerAstronSoc *17*:852.
D.Rawlins 1987. American Journal of Physics *55*:235. [Note *DIO 11.2* §G & fnn 26-27.]
D.Rawlins 1991H. DIO *1.1* ‡6.
D.Rawlins 1991W. DIO-J.HA *1.2-3* ‡9.
D.Rawlins 1993D. DIO *3.1-3*.
D.Rawlins 1999. DIO *9.1* ‡3. (Accepted JHA 1981, but suppressed by livid M.Hoskin.)
D.Rawlins 2002A. DIO *11.1* ‡1.
A.Robbins 2004. *Pledged: the Secret Life of Sororities*, NYC.
Strabo. *Geography* c.20 AD. Ed: Horace Jones, LCL 1917-1932.
Noel Swerdlow 1968. *Ptol's Theory of the Distances&Sizes of the Planets*, diss, Yale U.
Noel Swerdlow 1969. Centaurus *14*:287.
Noel Swerdlow 1989. JHA *20*:29.
Liba Taub 1993. *Ptolemy's Universe . . . Philosophical&**Ethical** Foundations*, Chicago.
Ivor Thomas 1939&41, Ed. *Greek Mathematical Works*, LCL.
Hugh Thurston 1998. DIO *8.1* ‡1.
Victor Thoren 1990. *Lord of Uraniborg*, Cambridge U.
Gerald Toomer 1984, Ed. *Ptolemy's Almagest*, NYC.
A.Van Helden 1985. *Measuring the Universe*, U. Chicago.
H.Vogt 1925. AstrNachr *224*:17.
B.van der Waerden 1963. *Science Awakening I* (Tr. Arnold Dresden), NYC.
B.van der Waerden 1970. *heliozentrische System . . . griech, pers & ind Astron*, Zürich.
B.van der Waerden 1984-5. ArchiveHistExactSci *29*:101, *32*:95, *34*:231.

‡3 The Ptolemy GEOGRAPHY's Secrets

[Which *GEOGRAPHY* Secrets Were Secret from Ptolemy?]

Distillate from 3 Decades of DR Researches into Ptolemy's *Geographical Directory*, 1979-2007[1]

Zero Longitude Revealed: Cape Verde Isles
Old Egyptian Accuracy vs Greek
Marinos' Date and Authorship
Astrologers' *Handiest Tables*

In Memory of a Brilliant Friend
AUBREY DILLER 1903-1985

A Why a Network of Exactly 360 Sites' Geographical Hours?

A1 The famous Ptolemy *Geographical Directory* (henceforth "*GD*"), popularly called "The Geography" or "Geographia", is in eight Books. It was commissioned in the 2nd century AD for the use of Serapic astrologers (§D5). We will here adopt the fine English edition of its text by Berggren & Jones 2000 (henceforth "B&J"). But don't miss the lovely new complete Stückelberger & Graßhoff 2006 edition (henceforth "S&G"). If you know German. And even if you don't. The *GD* begins with explanatory Book 1, which tells of Ptolemy's incorporation of thousands of sites' geographical places from the work of an earlier geographer, Marinos of Tyre. Then, Books 2-7 list about 8000 sites' positions, expressed consistently in **degrees** to 1/12th degree precision: longitudes in degrees east of the **Blest Isles** (Cape Verde Islands: §F4), and latitudes in degrees north or south of the Equator.[2] The *GD* then concludes with what DR contends (§A4) resembles and-or partly constitutes the data-base grid-network computationally (eq.1) underlying the precision-corrupted (§§D1, D5, & K10) positions of *GD* Books 2-7, namely: Book 8, whose data are expressed entirely in **hours** (not degrees), a list of 360 sites' longitudes in hours west or east of **Alexandria** (not the Blest Isles); and, instead of latitude, longest-days M (for Summer Solstice) in hours, where parallels at $1^h/4$ or $1^h/2$ intervals of M were called "klimata". E.g., longest-day $M = 14^h1/2$ was called the Rhodos klima where $L = 36°$ (via eq.1).

[1] These investigations were posted on the *DIO* website in 2006-2007, at www.dioi.org/gad.htm. Unless otherwise indicated, *GD* section-numbering here follows that of Karl Nobbe 1843-5 (henceforth cited as merely "Nobbe"), numbering which is also followed as closely as possible by the excellent new edition, Stückelberger & Graßhoff 2006 (henceforth "S&G").
Note that the present paper forgoes the use of accents for Greek words. Diller himself pointed out accents' superfluity, since classical-era Greek lacked them. During a DR 1987/6/1 visit to the Vienna Papyrus collection, the same view was expressed by the collection's chief, as well as by the able Dutch scholar Peter Sijpesteijn, who happened to be visiting the same day.

[2] *DIO*'s people are amazed at a long tradition of suggestions that the *GD* may well be the earliest geographical work ever to use spherical coordinates. This is less scholarship than a relic of Neugebauer-salesmanship for Ptolemy. (Origin: Neugebauer 1975 pp.337, 846, & 934; and see p.280 for parallel celestial semi-claims for the *Almajest*, despite the 2nd century BC Hipparchos *Comm*'s listing of dozens of stellar Right Ascensions & Declinations.) Long before Ptolemy, Strabo reported a Nile map consistent (Rawlins 1982N) with use of spherical geographical coordinates, and which goes back at least to Eratosthenes (3rd century BC) — a map so antique that it does not even use degrees.

A2 Aubrey Diller was (1983/3/6 letter to DR) the 1st scholar to point out the 360-site total and to suggest its deliberateness.[3]

A3 The longest-day M (in hours) at a site is a sph trig function of latitude L (in degrees) and the Earth's obliquity ϵ (also in degrees), by an equation known at least since *the 2nd century BC* (Bithynians Theodosios & Hipparchos) — a remarkable historical revelation, primarily owed to the mathematical investigation of Aubrey Diller 1934. [Readers not into sph trig may now skip from here to §B.]

The equation for computing each klima (§A1) attested for the 2nd century AD at *Almajest* 2.3:

$$\cos(15M/2) = -\tan\ L \tan\epsilon \qquad (1)$$

(where obliquity ϵ was usually taken to be 23°5/6 or [the discovery of Diller 1934] 23°2/3).

A4 Why different data-format for *GD* 2-7 vs *GD* 8? Two potential answers:

[1] Books 2-7, like the Important Cities part of Ptolemy's *HanTabl*, are in the form of Marinos' manual or map, presumably after his (though see §C1) systematic tectonic mass-alterations (*GD* 1.4 & B&J p.46) to force macro-geographical accord (through eq.1) with the above-hypothesized (§A1) network-grid-basis, which had been severely pre-corrupted by roundings (§§D1&D5) in tables long used by astrologers. Remarks at, e.g., *GD* 1.18 suggest that, like (following?) astrologer Hipparchos, Marinos clumped (§D4) cities under parallels. Also, Marinos gave primacy (*GD* 1.20.3 & 24.3; and below at §M6) to Hipparchos' 36° parallel (arc θ-κ-λ in Fig.1 [p.50]) through the east-Mediterranean island of Rhodos, suggesting both an astrological-tradition connexion and even the possibility that Marinos' table of rounded-longest-day parallels (for at least the Mediterranean-region) was a hand-me-down from Hipparchos, whose main observatory was located on Rhodos (D149), probably just north of the town of Lindos. (See Rawlins 1994L §F [pp.42-45].)

[2] The data of Book 8 are not for a map — but are in precisely (§D2) the hour-based form for astrologers' convenient use in computing a horoscope for a site other than Alexandria (D149), which was obviously the standard meridian for astronomical & astrological ephemerides in the Hellenistic world.[4] So *GD* 8 could have been called the *Handiest Tables* — perfectly set up for astrologers' convenience. Listing cities by longest-day superficially appears odd & cumbersome, and it gave no special aid when *using* data for maps. (To the contrary: §D3 [b].) However, astrological tables of the outdoor-invisible "Ascendant" (*Almajest* 2.8) — the corner-stone of astrological "house"-division for horoscopes — were simply easier to *computationally construct in the 1st place* (math provided at *ibid* 2.7), for longest-day values than for latitude values, back in the ultra-longhand days of early use of sph trig. The computational utility of longest-day is easy to show: for A = Ascendant, and ST = Sidereal Time, one can calculate:[5]

$$\cot A = (\cos[15M/2] - \sin ST)\cos\epsilon/\cos ST \qquad (2)$$

— simpler than using latitude L with a formula combining the foregoing 2 equations:

$$\cot A = -(\tan L\sin\epsilon + \sin ST\cos\epsilon)/\cos ST \qquad (3)$$

Thus, most available ancient astrological tables of houses (e.g., *Almajest* 2.8) were arranged (§D2 [1]) by klimata (§§A1&D4).

A5 Astrologers' other key invisible celestial point was the "Midheaven". But the Midheaven MH is latitude-independent. So, for any latitude, one need only consult (in *Alm* 2.8's tables) the "Sphaera Recta" columns (Toomer 1984 p.100), which tabulate the relation $\tan MH = \tan ST/\cos\epsilon$.

B The Greek *GD*'s Best Latitudes: Non-Greek Egypt & Phoenicia

B1 Fortunately, some cities' accurate latitudes appear to have survived; two particular groups are consistent (if we include 2′ stellar refraction and 1°/12 rounding) with that optimistic conjecture. In Lower Egypt (Rawlins 1985G p.260; *GD* 4.5.53-55): Memphis (D151), Cairo [fortress "Babylon"], and On [Heliopolis]. Note (in the context of astronomy-based latitudes): these 3 sites cluster around the ***most accurate astronomical-surveying-oriented*** building of antiquity, Giza's Great Pyramid,[6] whose latitude is correct at *GD* 4.5.54 (Cairo [Babylon], thus adjacent Giza): exactly 30°00′. In Phoenicia (modern Lebanon):

[3] See Aubrey Diller 1984's scrupulously-wrought establishment of the text of the entire contents of Book 8 at www.dioi.org/gad.htm. The total of his site-lists is 359. Nobbe's total is 358. But Nobbe omits Tarentum and Sousaleos, while Diller semi-omits Limyra. (Though, see end of this fn.) Merging the lists, we have exactly 360 sites in 26 sections, corresponding to *GD* 2-7's 26 maps. Sections: 10 of Europe (118 *GD* 8 sites), 4 of Africa (52 *GD* 8 sites), 12 of Asia (190 *GD* 8 sites).

I propose scholars' agreement upon a conventional numbering of all 360, based upon the sequence of Diller's XZ Codices, dovetailing with the UNK Codices (to cover sites either skipped), which follows Diller's desire to give primacy to the former. We use prefix D, to number every *GD* 8 site, so that "D x" refers to the x^{th} site. Adding to Nobbe's edition of *GD* 8: Tarentum (*GD* 3.1.12, 8.8.4) as site D53, Sousaleos (*GD* 3.3.4, 8.9.3) as site D63. (Note that we are dovetailing these two sites into Nobbe in passages that [exceptionally] already list more than one site — which may help explain these two oversights.) To Diller's version, we add Limyra (*GD* 5.3.6, 8.17.25) as site D193, Diller XZ Codices Asia-Map 1 site #22→#22a: "Myra", whose coordinates are identical to Nobbe's "Limyra" at *GD* 8.17.25. D192 is UNK's item#22, whose coordinates are identical to Nobbe's *GD* 8.17.23, "Myra" (*GD* 5.3.6). Note that one finds "22a" in Diller's hand in the left margin of his p.X13, showing that he suspected the need to add this site as the final touch to perfecting his epochal document. I.e., even at age eighty-plus, his sharp eye was still missing nothing!

[4] The very choice of longest-day (instead of latitude) as *GD* 8's measure of northerliness tips us off to the astrological connexion. (Hardly a stretch: recall that Ptolemy compiled the superstitious horoscope-delineation book that is still astrologers' bible: the *Tetrabiblos*. Note that the geographical table in his astrologer-oriented *Handy Tables* was at this stage still inconveniently in degrees.)

[5] It will help to provide an example, using the *Almajest* 2.8 table for Rhodos (D189) at Sidereal Time (the Right Ascension of the meridian, or Hour Angle of the Vernal Equinox) $21^h23^m36^s$ = 320°54′ (which is chosen to avoid interpolation in step 1, as will be evident):

Adding 6^h or 90° gives 50°54′ (the rising point on the Equator). Then, find 50°54′ in the *Almajest* 2.8's "Accumulated Time-Degrees" column for Rhodos (longest-day $M = 14^h1/2$, the basis of this column's ancient computation and arrangement): *Almajest* 2.8 (Toomer 1984 p.101). The value on the same row in the column "10° Intervals" is zodiacally 10° of Gemini or 10°GEM 00′ = ecliptically 70°, so that is the Ascendant. The Descendant (ecliptical point that is setting) is opposite: 250° or 10°SGR 00′ (10° of Sagittarius). The Midheaven (polar longitude of transitting zodiac point) is then found by linear interpolation on Toomer 1984 p.100: in the "Accumulated Time-Degrees" column, under the "Sphaera Recta" heading, we find 312°32′; 320°54′ (*ST*) exceeds this by 8°22′ of the 9°58′ interval corresponding to the 10° interval between 10°AQR 00′ and 20°AQR 00′ (in the column "10° Intervals"), so: add 10°(8°22′/9°58′) = 8°24′ to 10°AQR 00′, which yields Midheaven = 18°AQR 24′ (18°.4 of Aquarius) on the zodiac or ecliptical longitude 318°24′. The Nadir is opposite: 138°24′ or 18°LEO 24′. (This establishes the four cardinal points of the astrological houses for the chosen place & time. Division of each quarter into three parts then establishes the twelve astrological houses, but said division differed from one house system to another. Sph trig-based tables of houses probably go back to Theodosios of Bithynia, 2nd century BC.) Note in passing: finding Ascendant & Descendant (and thus house-divisions) is the sole use most modern astrologers have for geographical latitude. (Ancients also used latitude to enter parallax tables, but such scrupulousness is rare among today's astrologers.) Geographical longitude was used merely for additively converting (§D2 [3]) local time to ephemerides' standard zero-meridian, presumably that of Alexandria.

[6] All three latitudes are correct, perhaps a notable *Egyptian* achievment — since the *GD* lists Heliopolis (the Greek name for On) at the wrong latitude (exhibiting a peculiarly Greek error), not realizing (similarly at §K5) that it is the same place as the holy city called "On" by the Egyptians and Genesis 41.45. Note that the correct latitude is associated with the ancient Egyptian name, not the later Greek one. Details at Rawlins 1985G p.260.

Acre (Ptolemais), Tyre (§C2) & Sidon have errors of only a few miles, not quite as right-On as the Egyptian trio, but nonetheless impressive for antiquity — and highly unusual for the *GD*, suggesting that Marinos in Phoenicia (like Hipparchos at Rhodos) got particularly accurate latitudes from his own observations or from those of local astronomers or navigators, even while (fn 10) absorbing and relaying ordmag 1° errors for regions outside his or his associates' direct experience. Of these 6 sites, only Memphis (D151) is listed[7] in *GD* 8.

B2 The implication: those major cities not listed in *GD* 8 and civilized enough to desire and afford astronomers (note §D6) show a better chance of having accurate *GD* 2-7 latitudes (§§J2&K11) than those which don't.

C The Unresolved Mystery of Marinos the Phoenician

C1 Why hasn't it been previously noted that *GD* Book 1's extensive critical discussion of Mediterranean-region scholar Marinos' data fails to provide unambiguously a single Marinos latitude in degrees for any Mediterranean city? — or, indeed, any city within the Roman Empire.[8] So, though Marinos' latitude for the extra-Empire city Okelis (§H2) (D281) hints at inferior accuracy, we cannot tell for sure whether his Important City latitudes were as corrupt as the *GD*'s. I.e., the *GD*'s silence (fn 8) on Marinos' latitudes within the Roman Empire leaves open the possibility that his latitudes for Mediterranean or Roman Empire sites were accurate (if so, *GD* data-degradation occurred after his time) — and were thus suppressed for disagreeing with those of Hipparchos. (Similarly at fnn 8&19). But would encyclopedist Ptolemy expend the huge effort required for shifting 8000 data to dovetail with an underlying grid-network's few hundred important cities? (Ptolemy does report [*GD* 1.18] that much of Marinos' data for minor cities were incomplete and-or scattered, so serious labor [on someone's part] was required for subsequent estimation of positions' precise longitude & latitude, whether or no accurate or [§I7] even real.) Yet, if (fn 19) Marinos were an astrologer, why would he give longitudes in degrees — and worse, in degrees from the Blest Isles, not Alexandria? (Yet, Ptolemy's astrologer-fave *Handy Tables* did likewise.)[9] With arguments available in both directions, it is hard to be sure how much responsibility (for the corruption of *GD* 2-7's latitudes) is borne by Marinos. In favor of Marinos being a geographer, not an astrologer, is the measure of longitude in degrees from the Blest Isles. Which in turn implies that key sites' latitude-corruption from rounded longest-day klimata was not Marinos' doing.

C2 After all, how is it that an (apparently) eminent geographer from Phoenicia (a legendary naval center, where latitudes & stellar declinations would have been vital for navigating commercial vessels if nothing else) was ultimately — via his own or others' sph trig — depending, for his latitudes, upon crudely-rounded (§D6) astrological tables? (Of longest-day data: see below at §D1.) *If* he was. Note (§B1) that the Marinos-of-Tyre-based *GD* 5.15.5&27 latitude of Tyre is just about exactly correct (to its 1°/12 precision) if founded upon observations of circumpolar stars (affected by c.2′ of atmospheric refraction), a wise and effectively parallax-free latitude-determination method which may (§B1) go back to the time of the Great Pyramid.[10] Was the purpose of Marinos' geography naval? Or natal?[11]

D Astrologers'HandiestTables,InterRelations,AccuracyDegradation

D1 *GD* 8.2.1 states that the data of Book 8 were computed (via eq.1) from latitudes & longitudes. However, a detailed mathematical case has been made by Rawlins 1985G pp.260f that — though the remote-past origin of longest-day M data were obviously computed from latitudes — the highly (§§D5, K10, & L5) corrupted latitudes of major cities listed in *GD* Books 2-7 must have been computed (via eq.1) from **conventionally over-rounded longest-day *M*-data** (§A4) of just the sort[12] we see in Book 8. Flagrant examples appear below, e.g., Babylon (fn 16) & Vietnam (§K7). The suggestion here is that distortions in *GD* latitudes go back at least to Hipparchos, while the distortions in longitude probably occurred later than Hipparchos, since they involve a shift (fn 25; ‡1 §J4) from the Hipparchos 252000-stade Earth-circumference (fn 47) to the 180000-stade Earth-circumference which fellow-Rhodian Poseidonios seems to have switched to (Strabo 2.2.2) during the 1st century BC. (Though Taisbak 1974 eruditely wonders if this switch wasn't much later.) The *Almajest* was still using the larger Earth-size during the mid-2nd century AD, and the earliest rock-certain attestation of the smaller value's use is by Marinos, around the same time.[13] (Columbus' belief, that the shortest trip to China's Kattigara [D356] was

[7] Memphis' XZ (ms-tradition) longest-day (14^h) appears independent; but the ultra-precise UNK value ($13^h19/20$) looks like it may have been adjusted-to (computed-from: eq.1) an accurate latitude — suggesting (fn 12) post-Ptolemy tampering. See the learned observations of B&J (p.44) upon the two ms-traditions' relative trustworthiness and purity.

[8] A deliberate omission? I have doubts on that point; however, such silence would be similar to the slyness (see also fn 45) evident in his *Almajest* 3.1 suppression-silence regarding the times of the solstice-observations of Aristarchos (truncated: Rawlins 1985H) & Hipparchos (good to 1^h!), omissions 1st stressed by the late W.Hartner (letter to DR). See Rawlins 1991H §§A5&B3-5 [pp.50-52]. Note the key correlation: these two solstices are the only members of Ptolemy's extensive set of times of solstices & equinoxes that do not agree with his (Hipparchan) tables, and they are the only ones for which he hides the hour. (Each disagreed with the tables by 1/4 day.)

[9] The actual purpose of using the Blest Isles as longitude zero was probably to eliminate east-west positional sign-ambiguities — just as NPD (§H2) does for north-south.

[10] See Rawlins 1985G pp.255-256, as well as Rawlins & Pickering 2001; see also *DIO 13.1* [2003] (www.dioi.org/vols/wd1.pdf) [pp.2-11]. Similarly, Hipparchos knew his own latitude, but seems (§B1) to have been weak elsewhere, e.g., placing Athens a degree south of its actual latitude (Hipparchos *Comm* 1.11.3&8) and Babylon 2° 1/2 north (§L6) of its — both values copied (fn 10) by the *GD*.

[11] If latitudes based upon longest-day data were Marinos', this would raise the suspicion that he was an astrologer. (Possible, but — as already noted (§C1) — his reckoning longitude in degrees *and* from Blest Isles is contra this idea.) Were famous ancient astrologers analogous to modern popular-science writers and publications (www.dioi.sno.htm), where ubiquity, lucre, and hype obscure innumeracy, thereby nourishing blind-leading-blind multi-generational replication (e.g., www.dioi.sti56.html#rlbk) of unreliable scholarship?

[12] This is not to deny that some *GD* calculations went in the other direction (§D1) — nor even to reject the distinct possibility that *GD* 8 was all computed from *GD* 2-7 (data themselves already corrupted by calculations from a prior pool of longest-day data) as alleged. But some differences (fn 7) in the two mss-traditions (Diller's XZ vs UNK) occasionally remind us that post-2nd-century AD revisions of the *GD* 8 values may have attempted arranging consistency, in the same spirit that latitudes in *GD* 2-7 were adjusted at some point (at or before Hipparchos' era), according to the DR theory of the *GD*. Note that this theory (§D1) has here been limited to proposing the high likelihood that data of the *sort* (§D4) provided in *GD* 8 underlay *GD* 2-7's major cities.

[13] B&J p.14 n.10 show excellent judgement in rejecting a misguided but persistent tradition of manipulating the stade, to force disparate ancient Earth-measures to agree with each other or reality. See also Rawlins 1982N; Rawlins 1996C ‡1 §C14 & fn 47 [p.11]. The formerly unpopular but evidentially-insistent fact (‡1 §J3) that Eratosthenes' Earth-circumference was *genuinely* (not illusorily) high by 1/5, and Marinos-Ptolemy's too low by 1/6, is shown by 3 considerations:
[1] Ptolemy's expansion (by over 1/3) of the Rome-Babylon longitudinal distance between *Alm* & *GD*.
[2] The *GD*'s similarly large (33%-40%) systematic over-estimate of actual longitudes. (See the least-squares test of Rawlins 1985G p.264, leading to p.265's table of reconstructions.)
[The first scholar to sense that ancients had multiplied longitudes by adjustment-constants (when adopting new Earth-sizes) seems to have been Pascal Gossellin *Géographie des Grecs* 1790. (See his several tables exploring this hypothesis; also Rawlins 1985G n.22, which credits Gosselin & van der Waerden for this important realization.)]
[3] DR's neat common explanation of both C-values' errors from atmospheric refraction of light (§‡1 §A4 & §K) with 1/6 the curvature of the Earth.
All 3 of these evidences are consistent with each other and with realization that Marinos & Ptolemy (or their source[s]) adopted the genuinely smaller Earth entailed by his 700→500 stades-per-degree shift. Thus (‡1 §J2), there is not only no case-for but no longer even *any need-for* the literature's

westward not eastward, was much influenced by Marinos' over-tiny Earth.) Conversely, there are plenty of hints (e.g., Memphis' 13^h57^m: fn 7) that the majority of *GD* 8's non-major cities may have been directly computed (via eq.1) from data of the sort found in *GD* 2-7. (Note strong evidence that neither section was directly computed from the other: §E2.) E.g., the greater precision of *GD* 2-7 data is obviously often impossible (fn 26) to derive by computing from *GD* 8 — while the reverse is frequently possible (see §D5 for cause). Further, late copies of Ptolemy's *Handy Tables* (a work probably earlier than the *GD*) contain a list of c.360 Important Cities' (364 in Halma's ed.) latitudes and longitudes in degrees, very similar (though not identical) in content, bulk, and sequence to *GD* 8. It may be that Ptolemy simply computed the non-key sites of *GD* 8 from something like this list, as a handiest-possible (§A4) add-on to crown his *GD*.

D2 However *GD* 8 was accomplished, it was an astrologer's-dream Handiest Tables (§A4 [2]), *the only example of its type that survived from classical antiquity*:
[1] All latitudes expressed in longest-day, for (§A4 & eq.2) easy entry into tables of houses.
[2] All longitudes expressed vis-à-vis Alexandria, and
[3] in hours — for converting local time to Alexandria time, to enter Alexandria-based tables for computation of the zodiacal positions of Sun, Moon, & planets.

D3 B&J p.29 notes (as did Rawlins 1985G pp.261f) specific cases where key cities' latitudes must have been computed[14] from longest-day. Regarding the preface to *GD* 8:
[a] The preface's comments on map-distortions belong with parallel material back in *GD* 1.
[b] One of the most obvious arguments against *GD* 8's data being for (non-warped) maps is that longest-day data are not linearly related (§A4) to latitude. (Note shrinking of klimata-bands with recession from the Equator at, e.g., S&G 2:748-751.)
[c] The *GD*'s regional maps have come down to us. Granted, they are not originals; nonetheless, their fidelity to the *GD*'s regional dividers strongly suggest that these are the originals in essentials. Though the maps' margins bear longest-days marks (inevitably at large latitude intervals), the densely-marked, dominant north-south co-ordinate (linearly related to up-down distance on each map) is latitude in *degrees*. Which is necessary because these maps depict the locations of thousands of cities (not the hundreds of *GD* 8), the great majority of whose positions are not given at all in *GD* 8, while all their longitudes and latitudes are in *GD* 2-7. More indicative yet, the maps measure longitude not in *GD* 8's *hours* east or west of *Alexandria*, but in *GD* 2-7's *degrees* east of the *Blest Isles*.
(See the beautiful reproductions of several such maps between pp.128&129 of B&J.)
So: why would *GD* 8's preface be discussing the construction of regional maps actually based upon the data of *GD* 2-7? Is this more residual evidence (see further yet at fn 17) of patch-work authorship? What evidence connects Marinos to the construction of *GD* 8? The absence[15] of his native coastal Phoenicia from *GD* 8 proves his non-authorship of it.

D4 Tyre's absence from *GD* 8 only adds to the evidence (§E & §G1) that *GD* 8 is not directly connected to Marinos-of-Tyre's Books 2-7. So it would be wrong to over-claim that *GD* 8 is the father of *GD* 2-7. Uncle or cousin might be nearer the mark: §E1 §G2. For, longest-day data (the stuff of *GD* 8) are obviously the basis of the full work's

ever-reappearing attempts (see, e.g., Rawlins 1996C §C14 & fn 47 [p.11]) to claim that Eratosthenes got-the-right-answer for the Earth's circumference but expressed it using an undersized stade.

[14] A semi-ambiguity: *Almajest* 2.13 predicts the upcoming *GD* and refers to degrees vs the Equator for latitudes (like *GD* 2-7) but speaks of placing sites by degrees (the measure of Books 2-7) while using (fn 43 [1]) the Alexandria (D149) meridian of Book 8 (and of E.Mediterranean astronomers & astrologers); so it conclusively favors neither side on the relation between the *GD*'s two data-sections.

[15] In Nobbe's edition, at *GD* 8.20.18 (Jerusalem D247) the spelling of "east" changes from ανατολασ [anatolas] to εο [eo] for most of the rest of *GD* 8. If the switch (which occurs only in some mss) is meaningful, it is possible that it is connected: [a] to the compiler's departure (at about this point) from a map of the Roman Empire to an extra-empire map of different format (and less reliability), and this perhaps led [b] to the accidental omission of coastal Phoenicia, possibly due the two maps' different order of site-listing around the nearby seam. More patch-workery?

flawed grid-network of Important Cities' latitudes (§D5) — a grid which typically misplaced geographically-key cities by ordmag a *degree*, grossly mislocating the latitudes of key cities, e.g., Byzantion (D87 [Istanbul]) by 2° (though, as B&J p.29 n.37 rightly marvel, the false *GD* latitude continued to be believed at religiously non-empirical Byzantion until c.1000 AD!); Carthage (D131) by 4°, a huge error (revealed at Rawlins 1985G p.263 as due to false M) that enormously distorted maps of N.Africa (up to the Renaissance, over 1000^y later). Not to mention Babylon (D256) by 2°1/2 (fn 10; Rawlins 1985G n.13) — a discrepancy which is difficult[16] to reconcile with a modern historian-cult's non-empirical insistence (fn 46) that Greece had high-astronomy debts to Babylon. DR suspects (§A4) that the latitudinal shortcomings of the *GD*'s basic grid-network derive primarily from astrologer Hipparchos (not Marinos or Ptolemy): see at GD 1.4.2 (& 8.1.1) on Hipparchos' listing-clumping of cities of differing latitudes under the same klimata (§A3), for astrologers' convenient entry (§A4) into common longest-day-based tables of houses. This degenerative step typified the fateful laxity (www.dioi.org/cot.htm#twvr) which DR's §D1 theory proposes was the prime source[17] of latitude-accuracy's corruption in *GD* 2-7.

D5 Rounding klimata to fractions of hours (*GD* 8's practice) correlates to FAR cruder precision than rounding latitudes to twelfths of degrees, which is the precision of Books 2-7's data. Ancient longest-day tables often rounded M to the nearest $1^h/4$. (See, e.g., *Alm* 2.6, Neugebauer 1975 pp.728f.) But when using eq.1 in the Mediterranean region, *a longest-day error of merely 5 timemin would cause an error of nearly a full degree*. And ordmag 1° is the actual (terribly crude) accuracy of the data of Books 2-7. (Example of degeneracy [Vietnam] traced in detail at §K10.) This is (along with the plethora of places whose latitudes fall conspicuously upon exact klimata) one of the best arguments for the Rawlins 1985G theory that rounded longest-day data (*GD* 8's or its type) were the basis (§G3) for the key-city latitudes of *GD* 2-7. Note the historically vital (if paradigmist-verboten)[18] lesson imparted: competent ancient geography's heritage to us was corrupted — *crippled* (§G2) might be a more accurate indictment — *by the societal ubiquity of a pseudo-science*, astrology (§D4). But keep in mind (*DIO 4.3* ‡15 §C3) that Ptolemy worked for the newly-cosmopolitan, astrology-saturated Serapic religion, and doing horoscopes internationally requires (then & now) 3 manuals: astronomical tables, geographical tables, & interpretational handbook. Ptolemy's prime works were: *Almajest*, *GD*, & *Tetrabiblos*.

[16] It is common knowledge (§L6) that the longest-day value (*GD* 8.20.27) for Babylon (D256), $14^h5/12$, is a rounding of $14^h2/5$ — which is 3/5 of a day and the M basis of computation (§G2 [c]) of the revealingly inaccurate latitude $L = 35°$N (*GD* 5.20.6), $2°28'$ (148 nautical miles) too far north.

[17] There remains the question of whether Hipparchos was responsible for the fateful step of converting (via eq.1) crude tabular longest-day M values from hours to degrees of latitude L. In the light of DR's 2007 realization (www.dioi.org/cot.htm#hrbc) of just how admirably accurate Hipparchos' longitudes may've been, the odds that he was not the culprit are enhanced. Has the remarkable irony been noted that the *Geographical Directory* (at *GD* 8.1.1) itself scoffs at the common folly of clumping cities under parallels? Or that this contradicts *GD* 1.4.2, where Hipparchos is praised for his alleged aloneness in performing the very same clumping? Of course, the *GD* 8.1.1 complaint is merely that parallel-lists [like the pre-Ptolemy one of Pliny (77 AD): analysed at Rawlins 1985G p.262] waste time and space, but the statement is valuable in its suggestion of ancient currency of the very lists upon which the DR theory is founded. (Said currency could help a defense of Hipparchos as not-necessarily the unique source of the *GD*'s macro-errors; however, his attractive fame and his citation by both Marinos [*GD* 1.7.4] and Ptolemy [*Almajest passim*] argue in favor of his culpability here, though see speculation above on his longitudes [in this fn].) We needn't speculate anyway, on the existence of lists of a few hundred key cities' coordinates. Just such a list survives, e.g., in the Ptolemy *Handy Tables*, the Important Cities table of which (N.Halma 1:109f [1822]), appears closely related (§K4) to *GD* 8 in both quantity and sequence: 364 sites in all, with 12 not in *GD* 8, and 8 missing in *HT*. See also the two Important Cities lists (fn 43) provided in E.Honigmann 1929 [pp.193f]: Vatican 1291 [493 sites] and Leidensis LXXVIII [a comparable number of sites]. These lists' positions are [like *GD* 2-7] given entirely in degrees east of Blest Isles and north of the Equator.

[18] See ‡2 fn 67 & *DIO 2.1* ‡3 §C10 [p.31].

D6 Suggested Solution to Two Mysteries As shown in the tables of Rawlins 1985G p.262, *GD* latitude-errors for major cities are often sph-trigonometrically consistent with the §D1 theory. See eq.1 or Rawlins 1985G p.261, for the relevant math. See also discussion (*ibid* p.259) of a further revealing point: without the DR theory presented there & here (§C2), how could one reasonably explain two shocking oddities (which had evidently escaped the notice of previous commentators): [1] *GD* latitudes (as already noted) are *two ordmags* cruder than ancient astronomers' latitude-accuracy. (Roughly: a degree vs an arcmin.) [2] The *GD* latitude errors' large size (again: ordmag a *degree*) is comparable to that of its pre-expansion (fnn 13&25) sources' longitude errors — this, though: [a] The former should be 30 times smaller than the latter. (Or 41 times smaller, if eclipse-observations aren't taken as raw-data pairs.) [b] Real astronomers knew their latitude to ordmag an *arcmin*.[19]

E *GD* 8's Disconnect: *GD* a Hybrid

E1 The order of data-listing for *GD* 2-7 and *GD* 8 are similar. (And the former's 26 local maps correlate in designation and sequence with the latter's.) This suggests (§D4) some sort of inter-causation or co-causation. (*GD* 8.2.1's statement that *GD* 8's data are from degree-lists does not say that they were those of *GD* 2-7, though that may be the implication and-or the truth.)

E2 However, throughout the *GD*, we find repeated instances of differences in order-of-listing.[20] Which argues against *GD* 8 being computed directly from[21] *GD* 2-7 or vice-versa.

E3 Decades ago, Aubrey Diller pointed out to DR that the *GD* never mentions Book 8 — until the reader arrives there.

E4 DR has noted something similar: throughout *GD* 1, there is no mention of Alexandria,[22] Ptolemy's claimed home and his *Alm*'s prime meridian. By contrast, *GD* 1 mentions such sites as: Thule (D1), Ravenna (D56), Lilybaeum (D67), Carthage (D131), Rhodos (D189), Canopus (Ptolemy's true home), Syene (D154), Meroë (D165), Arbela (D261), Okelis (D281), Kattigara (D356), among many others. Since Ptolemy is a multiply-convicted plagiarist (Pickering 2002A; Duke 2002C), one may ask: is it credible that

[19] Rawlins 1982G p.263 fn 17. Note that *GD* 1.2 shows awareness that astronomical observation is the most reliable basis of latitude-measure. This returns us to the question: if sophisticated cities knew their latitude (§B2), how did most of these data get corrupted by astrologers? Was there a long astrological tradition (§C1) of geographical tables, which Marinos (note *GD* 1.17.2's semi-connexion of astrologers' klimata to Marinos) and-or Ptolemy felt forced to assent to the flawed important-cities latitudes of? Just as usually-equant-preferring Ptolemy may've felt forced to go along (in the *Almajest*) with Hipparchos' flawed but long-pagan-sacred eccentric-model solar tables.

[20] E.g., Nîmes (D29) & Vienne (D28): *GD* 2.10.10-11 & 8.5.7. (B&J p.106 vs p.122.) Kasandreia (D101) & Thessalonike (D95): *GD* 3.13-14 & *GD* 8.12.10&4. Pergamon (D178) & neighborhood: *GD* 5.2.14 & 8.17.10. Hierapolis (D237) & Antioch (D236): *GD* 5.20.13&16 & 8.20.8&7. Teredon (D259) & Babylon (D256): *GD* 5.20.5&6 & *GD* 8.20.30&27. Kattigara (D356) & Thinai (D355): *GD* 7.3.3&6 & *GD* 8.27.14&12.

[21] See §G1. For the consistent sites, either there were calculations of one section's data from the other (in one or both directions) or scrupulous attention was paid (fn 25) to math-consistency between the two sections (whether at the outset or during later editors' touchings-up) — though there are occasional inconsistencies, e.g., the longitude of Rome (D49): *GD* 3.1.61 puts Rome $36^\circ 2/3$ west of the Fortunate Isles, while *GD* 8.8.3 puts Rome $1^{h}5/8$ east of Alexandria. (Itself $60^\circ 1/2$ west of Blest Isles by *GD* 4.5.9, or 4^{h} [60°] by *GD* 8.15.10. See Rawlins 1985G n.25.) But $(60^\circ 1/2 - 36^\circ 2/3)/(15^\circ/\text{hour}) \approx 1^{h}7/12 < 1^{h}5/8$. Similar incompatibility: Salinae (*GD* 3.8.7, 8.11.4, D79). See also §K3.

[22] Nobbe 1:46 inserts Alexandria at the 14^{h} klima (*GD* 1.23.9), but it is clear from Müller 1883&1901 (1883) 1:57, B&J pp.85&111, and S&G 1:116 n.4 that this was not in the original, which (in *GD* 1.23) named only four klimata north of the Equator: Meroë [D165] (13^{h}), Syene [D154] ($13^{h}1/2$), Rhodos [D189] ($14^{h}1/2$), Thule [D1] (20^{h}). Selection repeated *GD* 7.5: B&J p.111. Note that Alexandria [D149] is mentioned at *GD* 7.5.13-14.

allegedly (*Almajest* 3.1) Alexandrian Ptolemy would write a preface to his *Geography* which never mentions his own city, when it is the prime meridian for his astronomical works, for his earlier-announced (*ibid* 2.13) forthcoming geography, and for *GD* 8?

F Blest Isles Ignored & Identified: the Cape Verde Islands

F1 Conversely, the Blest Isles, the *GD ekumene*'s west bound (and *GD* 2-7's implicit prime meridian), have no entry in *GD* 8. In *GD* 8, this linch-pin site is only mentioned at two places, rather *in-passing*: at *GD* 8's prime meridian Alexandria (*GD* 8.15.10) and at the *GD ekumene*'s east bound, Thinai (*GD* 8.27.13), where it is noted that Thinai is 8^{h} east of Alexandria and thus 12^{h} east of the Blest Isles.

F2 Yet another oddity: the *GD* repeatedly states that the Blest Isles are the west bound of the *ekumene*. (Though, curiously, not at *GD* 7.5.2, even while soon after saying so at *GD* 7.5.14.) Yet the writer of *GD* 1 does not explicitly state that all the longitudes of *GD* 2-7 will be measured from the Blest Isles; and the Blest Isles' has no entry in *GD* 8. Its position appears[23] under Africa at *GD* 4.6.34. Additionally, one notes that there is not a single absolute longitude in *GD* 1 — every longitudinal value is given in strictly differential terms. Now, if one is writing a preface to a compendium that provides the longitude-east-of-Blest-Isles of 8000 sites, one would think that the east-of-BI part just might get mentioned somewhere. Instead, *GD* 1 is completely non-committal regarding what will be the prime meridian of the work. And *GD* 2.1 (the preface launching the reader into the 8000 sites) is likewise. (If one were just grabbing — virtually unedited — a preface to another work, something like this could easily happen.)

F3 There are a few islands near Mauretania at about the latitude of the Canaries, which are the hitherto-standard identification of Ptolemy's Blest Isles. (E.g., S&G 1:455 n.200, which scrupulously notes that the identification of the Blest Isles with the Canaries is uncertain.) But these islands are not *GD*-listed at longitude zero; nor is the center of the real Canaries longitudinally beyond the real western hump of Africa, which is how the western-most anciently-known land obviously ought to lie.

F4 *GD* 4.1.16 lists a few non-zero-longitude islands (Paina & Erytheia) at latitude c.30°N and c.3° west of Mauritania, which would be the Canaries. But these are roughly *a thousand miles* north of Ptolemy's six "Blest Isles" which are listed by him at *GD* 4.6.34, at longitudes 0° (four) or 1° (two), at north latitudes ranging from $10^\circ 1/2$ to 16° — which is about right for the Cape Verde Islands. (Actual CVI latitudes: c.75 nmi N&S of 16°N.) The same isles are also visible[24] on *GD* maps, strung along a longitude of about 0° — 300 nmi west of the western-most point (hump) of Africa (Dakar, on Cap Vert) at a latitude that is again a convincing match for the Cape Verde Islands, *which are therefore firmly identified as the Blest Isles*.

F5 The *GD*'s knowledge of the Cape Verde Islands stands as a testament to ancient explorers' courage: they are c.300 nmi from the mainland. (By contrast, the Canaries are barely off the NW-Africa shore.) So the islands' discoverer was himself the nearest thing to an ancient Eriksen or Columbus. Over 1000^{y} before sailors discovered tacking, trips there were presumably extremely rare and hazardous. Possibly galley-slave rowing-power was the key to the ancients' knowledge of the Cape Verde Islands. And perhaps they were regarded as Blest because European civilization had not yet significantly uplifted the inhabitants by the introduction of its ever-brewing wars & their ever-resultant slavery.

[23] Thanks to Alex Jones for pointing this out.

[24] E.g., B&J plate 6 (c.1300 AD); same in plate 1, marked as "Fortuna insula". Also S&G 2:838 & volumes' inside-covers. Online at http://en.wikipedia.org/wiki/Image:PtolemyWorldMap.jpg, the same six "Fortunate" islands can be seen at the west end of Ptolemy's world map, again at a position pretty consistent with that of the Cape Verde Islands. The astonishingly persistent previous confusion presumably occurred because the 5^{th} of the 6 islands listed at *GD* 4.6.34 is called "Kanaria Nesos".

G Hours as the Route of All Evil in Ptolemy's *GD*

G1 Looking at *GD* 1-7 and *GD* 8 as separate sections of the *GD*, one must notice that each of the two sections' cross-citations of the other's prime meridian is paltry at best (and could well have been from later interpolation) — so let's keep our eye on the main point: there is no mention of the Blest Isles in the *preface* to *GD* 8, any more than there is any mention of Alexandria in the *forward* (*GD* 1) of *GD* 1-7. It would be hard to ask for better evidence that neither (§D1) section was the immediate *direct* source of the other's totality.

G2 But let us return to the essence of the DR theory (§§D1&D5, fn 12) that the data of *GD* 2-7 were based upon data of the *type* found in *GD* 8, and fix upon the main points regarding the source of *GD* 2-7's major-site data:
[a] Whereas all latitudes were originally measured angles (method: *Almajest* 1.12), the inaccuracy of the latitudes in *GD* 2-7 show that these data had been corrupted by subjection to crude rounding (§D5) for astrologers' longest-day tables in *hours*, before being computationally converted into the latitude-degree data that ended up in *GD* 2-7.
[b] All astronomically-based longitudes in *GD* 2-7 were originally in *hours*,[25] as noted in *GD* 1.4. This, because based upon comparisons of lunar-eclipse local-times.[26]
[c] Thus we have arrived at a hitherto-unappreciated realization (obvious example at fn 16): ironically, every jot of the astronomically-determined data of the basic network of cities underlying *GD* 2-7's thousands of *degree*-expressed positions, was at some point (during its mathematical descent from its empirical base) rendered in *time*-units: hours. As proposed in Rawlins 1985G.

G3 And, as a result of rounded longest-days (§D5) and Earth-scale shifting (§L3), these hour-data became the semi-competent-occultist conduit (§D1) for data-corruption which tragically destroyed a sophisticated civilization's laboriously accumulated high-quality astronomically-based ancient geographical data.

[25] Wrongly (fn 45), Ptolemy believed (*GD* 1.4&12-13) that eclipse-based longitudes were rare. (The method of finding longitude-differences between sites by comparing local times of simultaneously-observed lunar eclipses, was obviously well known. See, e.g., Strabo 1.1.12 or *GD* 1.4.2. Least-squares tests on ancient longitudes show that the eclipse method had been extensively used by genuine ancient scientists: Rawlins 1985G §§5&9 [pp.258-259 & 264-265].) And so he assumed that generally-accepted longitudes were primarily based upon travellers' stade-measured distances (terrestrial) instead of eclipse-comparisons (celestial) — a crucial, disastrous error, which undid generations of competent scientists' eclipse-based accurate longitudes-in-hours and thereby wrecked (§L3) the *GD*'s longitude macro-accuracy in angle. (Though not in distance: *idem*.) Note: said mis-step must have occurred before the hypothetical dovetailing (fn 21) of *GD* 2-7 and *GD* 8, perhaps (§D1) in the 1st century BC.

[26] A number of network-cities' *GD* 2-7 longitudes could have been calculated directly from *GD* 8 or its source, using Alexandria (D149) longitude (east-of-Blest-Isles) 60° 1/2 (*GD* 4.5.9) or 60° (*GD* 8.15.10). Some examples:
London (*GD* 2.3.27, 8.3.6, D4), Bordeaux (2.7.8, 8.5.4, D21), Marseilles (2.10.8, 8.5.7, D26), Tarentum [Diller 1984 Codices XZ Europe-Map 6 site #5] (3.1.12, 8.8.4, D53), Brindisi (3.1.13, 8.8.4, D54), Lilybaeum (3.4.5, 8.9.4, D67), Syracuse (3.4.9, 8.9.4, D68), Kyrene (4.4.11, 8.15.7, D146), Meroë (4.8.21, 8.16.9, D165), Kyzikos (5.2.2, 8.17.8, D176), Miletos (5.2.9, 8.17.13, D181), Knidos (5.2.10, 8.17.14, D182), Rhodos (5.2.34, 8.17.21, D189 — allowing for common [Rawlins 1994L §F3] ancient rounding of $1^h/8$ to 8^m), Jerusalem (5.16.8, 8.20.18, D247), Persepolis (6.4.4, 8.21.13, D271).
However, these could as easily have been computed in the other direction. The majority of less grid-critical sites' degree-coordinates couldn't (§§D1&D5) have been computed directly from those of *GD* 8 (at least in its present state), but could've gone the other way; e.g., Smyrna (5.2,7, 8.17.11, D179) & Pergamon (5.2.14, 8.17.10, D178).
Given the *GD* as it stands, if *GD* 8 is contended to be the direct ancestor of *GD* 2-7's longitudes, one would have to argue that the underlying network-basis was far less in number than *GD* 8's 360 sites — which, if we are speaking of sites whose longitudes (vs Alexandria) had been astronomically determined, would not (in itself) be an unreasonable contention.

H Precession and Aristarchos

H1 Precession is the difference in the length of the tropical and sidereal year, caused by a gradual shift of the Earth's axis — an ancient discovery which we can easily trace back to Aristarchos (not-so-coincidentally also the 1st astronomer to publicly announce that the Earth moved), since[27] he is the earliest ancient cited to two different year-lengths. Aristarchos flourished c.280 BC: 1 1/2 centuries before Hipparchos, hitherto generally regarded as precession's discoverer. Both of Aristarchos' yearlengths are provided at Rawlins 1999 §B7 [p.33]; see also Rawlins 2002A fnn 14&16 [p.8].
H2 Precession was known to the author of *GD* 8.2.3.[28] Thus, the *GD* 1.7.4 discussion seems awfully strange,[29] since it here quotes the statement of Marinos of Tyre (c.140 AD: §I1) that all the constellations rise&set in the tropical geographical regions — with the sole exception of UMi, which becomes ever-visible after a northward traveler passes latitude $+12^\circ 2/5$, Hipparchos' long-precessionally-obsolete NPD (North Polar Distance = declination's compliment) for α UMi. (I.e., modern "Polaris": the brightest star in UMi, and the most northern easily-visible UMi star for us; the most southern for Hipparchos.) And α UMi's NPD actually was $12^\circ 27'$ (Decl $= 77^\circ 33'$) at Hipparchos' chosen epoch, -126.278 (128 BC Sept.24 Rhodos Apparent Noon: Rawlins 1991H eq.28 [p.58]). Marinos further states that this parallel is 1° north of Okelis, which he mis-places (§C1) at $11^\circ 2/5$ N latitude.[30] (A poor estimate, since Okelis (D281) [modern Turbah, Yemen] is actually at $12^\circ 41'$N, $43^\circ 32'$E.) Yet, by Marinos' time (§H2), α UMi's NPD had precessed down to about 11°: in 140 AD, $10^\circ 59'$. So, his statements prove he didn't account for precession. But the most peculiar aspect of this matter is that *GD* 1.7.4 makes no comment at all on Marinos' flagrant omission of precession — and this though Ptolemy is (as usual) in full critical mode (alertly questioning [*GD* 1.7.5] whether any of Marinos' discussion is based upon the slightest empirical research), and though the writer of the *Almajest* certainly knew (*Alm* 7.2-3) the math of precession. Comments:
H3 There can be little doubt that the authors of *GD* 1.7.4 and *GD* 8.2.3 were not the same person.
H4 If Okelis were where Marinos placed it, α UMi's ever-visible circle would have been south, not north of Okelis.
H5 Has it been noted that, by the time of Marinos & Ptolemy, α UMi was (thanks to precession) no longer the most southern of UMi's seven traditional stars?! — η UMi and especially 3rd magnitude γ UMi were much more so. Indeed, for the time of the *GD*, γ UMi was *over a degree* ($1^\circ 04'$ at 160 AD) more southern than α UMi. (Shouldn't the "Greatest Astronomer of Antiquity" [‡2 §G2] have known this? — especially since he pretended he'd cataloged the whole sky's stars: *Almajest* 7.4. I.e., the *GD* 1.7.4 statement on α UMi disagrees not only with the sky but with Ptolemy's own tables.[31] Similar case at fn 45.) Thus, γ UMi had long since assumed the distinction (one interjected by Marinos, ironically) of being the outrider-star whose NPD determined whether a geographical region was far enough north to attain UMi-ever-visibility. (Note that *GD* 6.7.7 puts Okelis at latitude 12°N [and false-Okelis at $12^\circ 1/2$]; so, creditably, the *GD*'s Okelis latitude was closer to reality than to Marinos. Note also that 12° is almost exactly the theoretical

[27] Note: not a single historian has yet indicated publicly that he understands this rather self-evident point. (Though some have privately.) Which gives us hope that sociology can yet attain to the predictivity of astronomy. (See ‡2 Epilog [p.31].)

[28] *GD* 8.2.2 by the arrangement of B&J or 8.B.2 in Diller 1984 (the only reliable English translations) at *DIO 5*.

[29] Though some experts disagree: B&J p.65 n.23 & p.120 n.3.

[30] Is this a revised&multibungled re-hash of an original Hipparchos estimate that Okelis was on the arctic (ever-visible) circle of α UMi? — which would have been correct in 170 BC and OK to ordmag $0^\circ.1$ during his career.

[31] Even Ptolemy's very insufficiently precessed plagiarism of Hipparchos' star catalog has γ UMi $9'$ south of α UMi.

[www.dioi.org/fff.htm#csvv] ever-visible latitude for all of UMi at the *GD*'s epoch, since γ UMi's NPD was $11°56'+$ in 160 AD.)[32] As noted, the foregoing strongly suggests (see also §D4) that the same person did not write *GD* 1.7.4 and *GD* 8.2.3. And several other features suggest independently that the *GD* is a patch-work[33] opus. Thus, the above analysis of *GD* 1.7.4 provides another powerful augmentation of that evidential collection.[34]

I Marinos Mis-Dated?

I1 Nowadays, it seems to be almost universally assumed (e.g., Neugebauer 1975 pp.879 & 939) that Marinos flourished very early in the 2nd century AD, sometime during Trajan's reign, around 110 AD.[35] Which is curious, since in c.160 AD (or perhaps even later: §I2) Ptolemy refers to Marinos as (*GD* 1.6.1 emph added): "*the* most recent [of those] of our time" who have attempted a large geography. Now, if you were currently writing of a geographer of the mid-*1950s*, would you speak of him so? (*GD* 1.17.1 has been taken to indicate that Marinos was retired or dead by Ptolemy's day, but the passage is hardly unambiguous on that point — and would make more sense if Marinos' latest publication was merely 5 or 10 years past.)

I2 Moreover, Alex Jones points out (2007/5/23 conversation) that the forward dating of Marinos would help solve a problem first emphasized at Schnabel 1930 p.216: when did Ptolemy become aware that people lived south of the Equator? *Almajest* 2.6 says the S.Hemisphere is unexplored, though Marinos says otherwise and (§M1) the *GD* agrees. This implies, since the *Almajest* might have been compiled during Marcus Aurelius' reign (Rawlins 1994L Table 3 & fn 45 [p.45]), that Marinos' date could be as late as c.160AD.

I3 The argument adduced to date Marinos to much earlier (than Ptolemy) is that Marinos' work took into account names of sites reflecting the changing Empire, e.g., Trajan in Dacia (*GD* 3.8, 8.11.4 [roughly modern Romania]) up to c.110 — but not later in Parthia (*GD* 6.5, 8.21.16-18 [roughly modern Iran]) and north Africa. But how sure is such tenuous reasoning? How strongly should it rank? — in the face of:

[a] *GD* 1.6.1's plain statement of Marinos' contemporariness, and

[b] the incredibility of the long-orthodox implicit assumption that, in a busy mercantile empire, a succession of macro-geographers (*GD* 1.6.1 implies plurality) suddenly ceased for 1/2 a century!

I4 Moreover, why assume that Marinos adopted all the latest name-changes? Ptolemy didn't: his preface's criticisms complain (*GD* 1.17.4) that Marinos misplaced the Indian trading town Simylla (D330) and didn't realize that the natives call it Timoula. Yet the *GD*'s data-listings (*GD* 7.1.6 & 8.26.3) both retain Marinos' name: Simylla, not Timoula. B&J n.53 (p.76) note an even more revealing careless retention:[36] Marinos' Aromata latitude. So, what should be tested isn't whether *all* but whether *any* post-Trajan geography appears in the *GD*.

I5 Especially since it doesn't seem that there'd likely be many changes. After all, it's well-known that Dacia was the last solid addition to the Roman Empire. (It may not be coincidental that around this time the Roman army was becoming predominantly alien-mercenary.) Trajan's army was of course stronger than Dacia's. (So, we know who ended up with Dacia's gold.) But it wasn't stronger than that of the Parthian Empire; thus, the attempted-rape[37] victim got in all the Part'n shots, and the puppet ruler whom Trajan had placed into power at the then-capital (Ctesiphon [D262], near Babylon [D256]) passed on soon after, as did Trajan (117 AD). Trajan's adventure in Parthia having been an expensive failure, his two successors chose not to try expanding the empire. Hadrian (117-138) did not share certain current warlords' fiscal profligacy. Similarly for Antoninus (138-161 — which takes us up to the time of Ptolemy's geographical work). These points urge some caution before we draw conclusions on Marinos' date from lack of the-very-latest Parthian information.

I6 Next, we note that the most notorious exception to the non-expansion policy of Hadrian occurred in Palestine. In 130 AD, he visited Jerusalem and ordered its re-building. Since Hadrian's family name was Aelius, he re-named Jerusalem: "Aelia Capitolina". (His supervision evidently triggered a local revolt — put down in 132-134, with Hadrian sometimes on the scene.) So, does the *GD* reflect the change? Yes: *GD* 5.16.8 lists "Ierosoluma [Jerusalem], which is called Ailia Kapitolias". And *GD* 8.20.18 lists "Ailia Kapitolias Ierosoluma" without further comment but obviously reflecting the same up-to-date[38] information. Therefore, we have indication that both the *GD*'s data-sections (*GD* 2-7 and *GD* 8), previously adduced to date Marinos to c.110, actually contain material from the 130s or later.[39]

I7 An example of the fruitfulness of the foregoing:
Almost 2 centuries ago, H.Müller made the brilliant observation that a *GD*-listed N.German town "Siatoutanda", was probably non-existent, just (another: fn 45) Ptolemy-compilation mis-read of a foreign language: Tacitus' Latin description (*Annals* 4.73) of a N.German battle-retreat ("ad sua tutanda"). This does not stop our ancient geographer from providing (§C1) highly specific[40] coordinates: longitude 29° 1/3, latitude 54° 1/3 (*GD* 2.11.27). As is

[32] Likewise, 1000 nmi to the southwest of Okelis: regarding the location of the two lakes feeding the Nile, the *GD* astutely makes a major correction to Marinos in placing both lakes much nearer the Equator than Marinos had them. (In reality: the Equator runs through the eastern source, Lake Victoria. And the western source, lake-pair Edward & Albert, straddles the Equator.) Remarkably, the *GD*'s maps of Africa were still consulted by geographers in the mid-19th century, when these lakes were finally 1st reached by Englishmen. (See *J Roy Geogr Soc 29*:283, *35*:1, 7, 12-14; *Proc RGS 10*:258.)

[33] Also fn 45. See Rawlins 1985G p.260 (On vs Heliopolis: fn 6) and p.266 & fn 6. We find similar hints of patch-workery throughout the *GD*, e.g., at *GD* 1.24.11-vs-17, as the lettering for two consecutive projection-diagrams are needlessly shuffled. (See B&J p.91 n.80.) See also another Ptolemy-compiled work, the *Almajest*, where, e.g., the mean motion tables' Saturn→Mercury order of the planets (*Alm* 9.3-4) is the reverse of the Mercury→Saturn order followed in their fraudulently (Rawlins 1987 pp.236-237 item 5; Rawlins 2003J) alleged derivation at *Alm* 9.6-11.8. For more such patch-work indications, see frequently here, and at Thurston 1998 end-note 17 [p.17] & Rawlins 2002V §C [p.76].

[34] Indicia of such patch-workery in the *GD* are frequently noted here, due to the inexplicably-repeated modern claim of coherent unity for each of Ptolemy's works.

[35] Quite aside from the present discussion: for compelling evidence against this date, see H.Müller's clever discovery: §I7.

[36] These situations remind one of the common modern mis-interpretation (Rawlins 2002B fn 7 [p.12]) of *Almajest* 3.7 to mean that no Babylonian astronomical records came through to Ptolemy prior to 747 BC, though the actual statement is rather that *continuous* records went back that far.

[37] Over 4 centuries of botheration, Parthia repelled three Roman invasions: [1] swallowing the army of Crassus (suppressor & crucifier of Spartacus, and member of the 1st triumvirate), [2] exhausting emperor Trajan, and (after a temporary setback at Marcus Aurelius' hands) [3] slaying last pagan emperor Julian the Apostate (unless he was fragged). And, yes, "parting shot" is thought to come from Parthian archers' tactic of shooting arrows even when retreating or pseudo-retreating.

[38] Such an explicit update is rare in the *GD*'s data-body. Another such passage, even more unusually discursive, is found at *GD* 7.4.1, where it is stated that Taprobane (modern Sri Lanka [though known as Ceylon in Diller's & DR's youth]) was formerly called Simoundou but is now called Salike by the natives. Comments are even (very atypically) added, describing Salike's women and local products ranging from meal & gold to elephants & tigers. It seems likely that the mention of both Ailia Kapitolias and Salike were late additions to the *GD*, a point we will shortly (fn 39) make use of. (Note: Taprobane [*GD* 8.28] is the last map in the *GD*, though [given its location] it should obviously have been covered before the *GD* listings get to China. I.e., we have here yet another symptom of a late add-on.)

[39] Following the revolt's suppression, Judaea was re-named "Syria Palestine" and Rome henceforth (c.135) eliminated the term "Judaea". The fact that it is retained in both the body (G2-G7) and Book 8 of the *GD*, taken together with the re-naming of Jerusalem leaves us with a bracket-argument in favor of dating Marinos to about 135, which is indeed of Ptolemy's time — as he said.

[40] The "Siatoutanda" goof reminds one of St.Philomena, of whose "life" whole books used to be written (DR possesses a copy of one), though she never existed: "Philomena" turned out to be just an

all-too usual in the ancient-science community, Müller's novel and obviously valid discovery has been doubted on grounds so tenuous (in comparison to the compelling evidence in its favor) as to make one wonder whether anything ever gets resolved in this field, no matter[41] the power of relative evidence. Against Müller, it has been argued (see sources cited at B&J p.28 n.34) that Tacitus *Ann* was published in 116 AD, which is after the (inexplicably-widely-believed) upper-limit date (110 AD) for Marinos. (But the 110 date is so far from firmly established that one should reverse[42] the situation: instead of using the date to exclude H.Müller's finding, use the HM finding to help establish a lower limit for Marinos' date.) So we recognize that H.Müller's discovery contributes importantly to the evidence suggesting that conventional wisdom on Marinos' date is suspect, and thus that there is little trustworthy evidence against our proposal that Marinos was much nearer Ptolemy's contemporary than is now generally understood.

J Tyre: Missing Home-City of Book 8's Once-Supposed Source

J1 The most peculiar coincidence in the history of ancient geography will turn out to be a lucky break for scholars of the *GD*: incredibly, Marinos' native Tyre is absent[43] from *GD* 8. (Curiously, this telling point has been overlooked in the literature.) And, in a context of questionable authorship, we must likewise notice (§E4) that Ptolemy's alleged home-city (Alexandria) is missing from *GD* 1.

J2 Marinos is clearly identified as of-Tyre (*GD* 1.6.1). Indeed, Tyre (Phoenicia) is cited doubly and with accurate latitude — highly exceptional on each count — at *GD* 5.15.5&27: 67° E of Blest Isles, 33° 1/3 N of Equator. (The latitude is correct [see similarly at §K11] if we account for refraction of pole-star light and 5′ rounding.)

J3 Thus, we conclude that *GD* 8 (in the form we have it) was not compiled by Marinos.

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over-imaginative later mis-read of a fragmentary ancient stone inscription (found in the catacombs of Rome on 1802/5/25): "LUMEN PAX TECUM FI", which was "restored" as a reference to FILUMEN or Philomena. This was enough to launch (starting c.1805 in the super-religious Kingdom of Naples) a cult, special novenas, the usual "miracles", and (from devotees' revelations) a detailed biography of her life & martyrdom. The Roman church creditably removed her from the list of saints about a 1/2 century ago.

[41] What says this about the field? See *DIO 7.1* [1997] ‡5 fn 40 [p.33] (www.dioi.org/vols/w71.pdf). Note the Velikovskian context.

[42] Similarly, when (1999/10/1) dim atmosphere proponent B.Schaefer imparted to DR his intention of testing the Ancient Star Catalog's authorship by assuming 0.23 mags/atm opacity, DR immediately suggested that it would be far more fruitful to use Hipparchos' authorship (which had by then been obvious to serious astronomers for centuries) to test for ancient atmospheric opacity. BS didn't listen, so this important and revealing project — proving beyond any question that man (not nature) is the prime cause of present atmospheric opacities ominously higher than ancient skies' — was instead masterfully and independently established by Pickering 2002A §§D2-D5 [pp.11-12].

[43] Tyre's absence from *GD* 8 has several non-neatnesses. While Tyre is also missing from the Important Cities lists in late copies of Ptolemy's *Handy Tables* (Halma ed.), Tyre does reside in two 9^{th} century copies (published in Honigmann 1929), which are far older than our earliest mss of the *GD*, and each contains (fn 17) c.100 more sites (than *GD* 8): Tyre is city #307 in Vat 1291, #160a in Leid.LXXVIII. In the latter ms, Tyre is counted secondarily; which suggests that, if paring occurred, Tyre was expendable. The superficially attractive interpretation is to wonder if *GD* 8 is a Byzantine-era add-on, which reflected a shrinking of the number of sites from nearly 500 to just 360.
The problem with that theory is format: *GD* 8 differs generically (from all other surviving Important Cities lists, which uniformly are in longitude degrees east of the Blest Isles and latitude degrees north of the Equator) by: [1] using Alexandria (fn 14) as prime meridian (astrologer Ptolemy's preference); and [2] providing data entirely in hours, *just* as ancient astrologers preferred (§G2 [a]). This argues strongly that *GD* 8 goes back in time at least as far as Ptolemy.

K Landlubber Ho! Wrapped China Negates the Pacific

K1 It is well-known that the farthest-east region of the *GD*, China, portrays a non-existent continuous roughly-north-to-south coast (blocking any route to the Pacific) beyond the South China Sea, near longitude 180° (12^{h}) east of the Blest Isles or 120° (8^{h}) east of Alexandria, stretching from near the Tropic of Cancer, all the way south to Kattigara at 8° 1/2 S. latitude — effectively wrapping China around the Indian Ocean's eastern outlet. Latitude-longitude coords for 18 China sites are found in *GD* 7.3 (Renou 1925 pp.62-65).

K2 But, according to the previously-broached §D1 theory, all of this geography hinges upon the underlying grid-network: *GD* 8 and-or its kin. If we look at the *GD* 8.27.11-14 China data, we find that the situation of all China hinges upon just 3 cities' hour-data (longest day & longitude east of Alexandria, according to Diller 1984's XZ mss): Aspithra [D354] ($13^{h}1/8$, $7^{h}2/3$), Thinai [D355] ($12^{h}5/8$, 8^{h}), Kattigara [D356] ($12^{h}1/2$, $7^{h}3/4$). Anything wrong with *GD*'s China is wrong in this trio.

K3 For Thinai (D355), *GD* 7.3.6's latitude (3°S) jars with *GD* 8.27.12's longest-day $12^{h}3/4$ north, which would be correct for about latitude 12° 1/2 N.

K4 Fortunately, Vat 1291's Important Cities (fn 17) lists the same 3 cities (only) for China. (Honigmann 1929 p.206: cities #443-#445; no China listings in Leid.LXXVIII.) And on Thinai, it provides confirmation of *GD* 8 (not *GD* 7), listing Thinai at 13°N. Which suggests that the 3°S of *GD* 7 is either a scribal error (missing the *iota* for ten) or perhaps is differential: 3° south of Aspithra (16° 1/4N). Either way, it seems that 13°N is correct, as listed by Vat 1291.[44] (S&G 2:734 for Thinai has *GD* 7.3.6's 13° latitude.)

K5 Finally, we observe that Kattigara's latitude in degrees is the same in both Vat 1291 and *GD* 7.3.3 — but in the former it is *north* latitude (which makes way more sense for a Chinese city), correctly contradicting the impossible southern latitude of both *GD* 7.3.3 & *GD* 8.27.14. The matter gets even more interesting when we check our corrected position for Kattigara: 177°W (of the Blest Isles) & 8° 1/2 N — that is precisely the *GD* 7.3.2 position of Rhabana. Therefore (not for the 1^{st} time: §H5), the *GD* may have used two (or more) names for the same place.

K6 Thus, when we examine the underlying-grid trio for China, the two negative (southern) latitudes both appear so shaky that we can dispense with all negative signs for China — which eliminates the above-cited fantastic N-S coastal-bar to the Pacific.

K7 There is a disturbing pattern to the *GD* 7 latitudes of the only four S.China Sea cities on the Vietnam coast which are listed in *GD* 8 (in order N-to-S): Aspithra, Thinai, Kattigara, Zabai. These cities' *GD* 7.2-3 latitudes are, resp, about equal to: 16° 1/4, 13°, 8° 1/2, 4° 3/4 — which are suspiciously close to what one would compute indoors via sph trig (eq.1) from a quarter-hour-interval klimata table: Aspithra (D354) 13^{h}, Thinai (D355) $12^{h}3/4$, Kattigara (D356) $12^{h}1/2$, Zabai (D348) $12^{h}1/4$. (And, indeed, these are the values Diller found in *GD* 8's UNK mss-tradition.) This looks even fishier when one recalls (above) that these are the only 4 cities on the Vietnam coast which are listed in *GD* 8, where only longest-days (the stuff of klimata-tables) are provided for N-S position. (Even the precise $13^{h}1/8$ variant discussed in fn 44 for Aspithra, perfectly matched what may [*idem*] have been merely a scribal error: 18° 1/4.) Obviously assuming exactly-correct latitudes here is risky when dealing with such rounded data. Conclusion: we must also use verbal descriptions, if we wish to have any chance of solving this section of the *GD*.

K8 So, where and what are these cities? *GD* 7.3.3 refers to Kattigara (which has a 1^{st} syllable like Cathay's) as a Chinese harbor, near walled cities and mountains. So there's

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[44] The same Vat 1291 list gives 18° 1/4 N latitude for Aspithra (not the 16° 1/4 N latitude of *GD* 7.3.2, corresponding to longest-day $13^{h}1/8$ (§K7), the very Aspithra longest-day value listed in Diller's XZ-tradition mss. (One is tempted to ask if 18° 1/4 latitude [*idem*] was the true original latitude — or was later forced to agree with $M = 13^{h}1/8$? But it could have just come from a scribal error.) In Nobbe, *GD* 8 lists Aspithra at longest-day "about" 13^{h}, which corresponds to latitude $16°+$, agreeing with the *GD* 7.3.5 Aspithra latitude in Nobbe and Renou: 16° and 16° 1/4 N, respectively.

little doubt that we are on the Asian mainland, in the area of Vietnam-China. From *GD* 1.14 (B&J pp.75-76), we see that the original naval report (used by Marinos) indicates that a sea voyage (coastal: B&J p.27) from around Bangkok (Balogka, *GD* 7.2.25) at the north end of the Golden (Malay) Peninsula to the S.tip of Vietnam was a 20^{d} trip, with a few more days to Kattigara from there. (See the balanced discussion of B&J pp.155-156.) The *GD*'s supposed direction to Kattigara (left [east] of south) is obviously confused. I suspect that the ancient cause was a common land-lubber misinterpretion: "south wind" (which means wind *from* the south) was taken as *towards* the south — thus, following a "south wind" (*GD* 1.14.1; B&J p.75) was mis-taken (at *GD* 1.14.6) to mean sailing with a wind blowing southward. (Compare to B&J p.76.)

K9 Additionally, the order of the two sailing instructions could have been inadvertently reversed; the original would probably have said: swing left, and use the south wind.[45]

K10 DR's attempt at a sensible reconstruction of the original:
After the southish (really SE) trip to Vietnam's S.end, Zabai (D348), one turns northish and curves to the left around the hump of Vietnam, shortly arriving at Kattigara (D356) — which was probably about where resides the harbor long called Saigon. (Re-named Ho Chi Minh City. For now.) The real Saigon is just north of 10°N, so the *GD* is off by less than 2°, which is about as big an error as one will find caused (§D5) in this region by computing latitudes (eq.1) from nearest-quarter-hour-interval klimata. Whoever originally cubby-holed Saigon in a klimata-table found that 10° didn't fall exactly on a klima: the longest-day computed from 10° latitude would be about $12^{h}3/5$, and the nearest klima to that figure (in his quarter-hour klimata table) was $12^{h}1/2$, so: he put Saigon there, and thereby degraded the latitude's accuracy by 2°. This, in microcosm, is the story of why the *GD*'s mean latitude error is so poor: ordmag 1° (§D5), despite contemporary astronomers' achievement of knowing their latitudes ordmag 100 times more accurately. (See citations: Rawlins 1982G, Rawlins 1982C, Rawlins 1985G.)

K11 Barely-inland Aspithra (D354) could be Da Nang (actually at 16°02′N). And well-inland Akathara's latitude, 21°1/4 (*GD* 7.3.5), matches Hanoi (real latitude 21°02′N) within c.0°.2. Moreover, the Akathara corresponding longest-day ($13^{h}1/3$) is not near enough to a quarter-hour value to compel us to believe that the latitude was computed from a klima's rounded longest-day — which is consistent with the fact that Akathara does not appear in *GD* 8. Perhaps just as well! — for preservation (§B2) of latitudinal accuracy. The *GD*'s failure to notice prominent Hainan Island (which nearly blocks off the east side of the broad Tonkin Gulf) suggests that the sailors whose reports Marinos used, had routinely hugged the Vietnam coast as far as Hanoi and the west Tonkin Gulf region — but had never ventured further north — and so these sailors had never reached Hong Kong or beyond.

[45] Would linguistic problems (in the babel of antiquity) have contributed to these errors? (Marinos likely wrote in Greek; otherwise, Ptolemy could not have used him for a whole book.) For Ptolemy, it probably wouldn't have been the 1st time. He appears to have sloppily misordered (*GD* 1.4.2) simple, well-known data regarding the famous lunar eclipse that occurred shortly before the Battle of Arbela (D261 [modern Irbil, lately a north Iraq hot-spot]) also seen at Carthage (D131), by (www.dioi.org/cot.htm#xptx) screwing-up Latin text of (or like) Pliny's accurate description of that −330/9/20 event, thereby attaching Arbela's eclipse-time to Carthage! Despite lunar eclipse after lunar eclipse occurring in Ptolemy's lifetime (three recorded at Alexandria in under 3^{y} at *Almajest* 4.6: 133-136 AD), this antique record was his sole example (!) of how to determine longitude astronomically. (See fn 25.) Further suggestion of patch-workery (also §L1): the Ptolemy account of these eclipses is in gross disagreement with not just the real sky but *just as grossly with his own luni-solar tables*. See similar situations for Polaris at fn 31 and for Venus at Rawlins 2002V §B3 (p.74). And his solar fakes also show the same propensity to swift-simple, not-even-tabular fraud and plagiarism. (Anyone researching Ptolemy should keep ever in mind that he was shamelessly capable of every brand of deceit. See, e.g., fn 8; also Thurston 1998 ‡1 ⊙2 [p.14].) This eclipse was so famous that one would suppose it was widely-written-of. Thus, it is doubly weird that Ptolemy could make such an error. The suggestion here is that, as an astrologer for a Serapic temple, he was isolated from real scientists. (As perhaps Hipparchos had also been: §B1.)

L Brief Comments & Hypotheses on Several Subjects

L1 Parts of the *GD* show familiarity with the Euphrates River by name. (E.g., *GD* 1.12.5, 5.20.1-3&6.) So: why does *GD* 5.20.6 refer to Babylon as merely being "on the river that goes through Babylonia"? This appears to be just unconsidered quick-info-transplant from an uncited source — and yet another (see §D3, etc) hint of patch-workery.

L2 B&J p.44 notes that from *GD* 5.13 on, the most trustworthy ms (X) bears no coordinate data. Since the dataless lands were acquired late (after 100 BC) if at all by the Roman Empire, one might wonder if this oddity reflects dependence of the *GD*'s data (up to that point) upon early Greco-Roman lists, maps, or globes. Perhaps of Hipparchos' epoch.

L3 Marinos' *ekumene* was overbroad: a 225°-wide known-world, 5/8 of a wrap. This was justly revised at *GD* 1.12-14 to a smaller and much more accurate half-wrap breadth of 180° (see fn 48 or *GD* 1.14.10), though B&J n.53 (p.76) rightly note the over-roundness here: Ptolemy aimed to get 180° — "by hook or by crook".
Had Marinos-Ptolemy not implicitly trusted (‡1 §J4; Rawlins 1985G n.14) E-W stade-measures over eclipse-measures of longitude (contra priority promo-announced at *GD* 1.4) and thus altered all degree-longitudes by a constant Earth-size-shift factor (fnn 13&25; Rawlins 1985G p.264) when switching from 700 stades/degree (§L6) to 500 stades/degree, then the known-world's *GD* breadth in degrees would have been quite close to the truth — as was Ptolemy's breadth in distance (error merely ordmag 10% high): 90000 stades = 9000 nmi from BlestIsles-W.Europe to Java-E.China-Vietnam.

L4 Thus, strangely (since latitudes were much easier for the ancients to measure accurately: §D6), the Ptolemy *ekumene* (Fig.1) *longitudinal stades-distance-across is not less trustworthy than his latitudinal stades-distance-across*.

L5 We met a similar surprise earlier in finding (§D6 [2]) original longitude error-noise not worse than that in latitude. The upshot of both findings is an important broad insight: the merits of the *GD* are more geographical than astrographical.

L6 Some scholars aver that an ambiguous discussion at Strabo 2.1.34-35 shows that Hipparchos knew Babylon's true latitude, 32°1/2. But the argument is vitiated by the high sensitivity of its key triangles' north-south sides, to slight uncertainties of ordmag 100 stades in other sides. Confirmatorily lethal: Strabo's very next paragraph (*ibid* 2.1.36) unambiguously, unsensitively reports that Hipparchos placed Babylon over 2500 stades north of Pelusium (D150), which was well-known (in reality [31°01′N] & at *GD* 4.5.11 [31°1/4]) to be near the same 31° parallel as Alexandria (*GD* 4.5.9). (Opposite sides of the Nile Delta: Alexandria-Canopus on the west, Pelusium on the east. Contiguous entries in *GD* 8.15: items 10&11 = D149&150, respectively.) At Hipparchos' 700 /1° scale (Strabo 2.5.34), this puts Babylon (D256) rather north of 31°1/4 + 2500 stades/(700 stades/1°) = 34°5/6-plus — i.e., at 35°N, just the grossly erroneous value we find at *GD* 5.20.6 and (effectively) at *GD*8.20.27 (fn 16) and on all other extant ancient *Greek* Important-City lists.[46] More germaine to the present investigation: this finding leaves still-uncontradicted our proposal (Rawlins 1985G p.261) that Hipparchos was (fn 10) the ultimate source of the corrupt state of the *GD*'s network's key latitudes.[47]

[46] A consideration which alone could serve to gut the entire long-orthodox Neugebauer-group fantasy (§D4) that high or even low Greek math-astronomy was derived from Babylon. Note that the same Strabo passage shows that Eratosthenes' latitude for Babylon was as erroneous as Hipparchos' but in the other direction. I.e., the entire Greek tradition had no accurate idea of where Babylon was, despite by-then long-standing contacts that had transmitted, e.g., invaluable Babylonian eclipse records.

[47] It has been remarked that the Strabo 2.5.34 intro to his discussion of Hipparchos' klimata appears to state that Hipparchos was computing celestial phenomena every 700 stades (i.e., every degree) north of the Equator. But since the lengthy klimata data immediately following are instead almost entirely spaced at quarter-hour and half-hour intervals, DR presumes that the original (of the material Strabo was digesting) said that Hipparchos was providing latitudes (for each klima) in stades according to a *scale* of 700 stades/degree, a key attestation that Hipparchos had adopted Eratosthenes' scale.

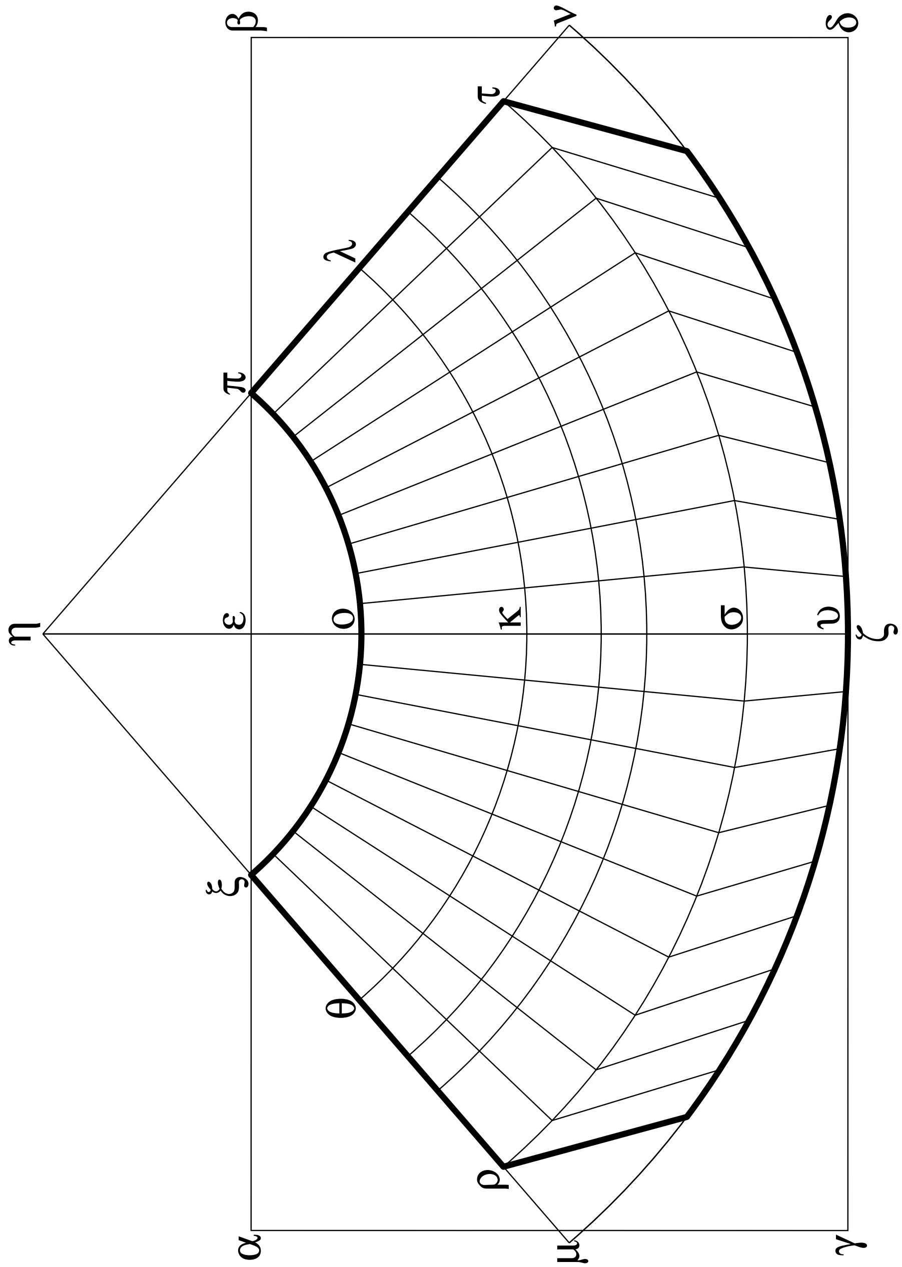

Figure 1: Ptolemy's 1st projection. *Ekumene* demarcated by dark bound.

M Ptolemy's 1st Planar World-Map Projection

From Where-in-the-World Arrived That 34-Unit Vertical Strut from Its Top (ε) to Its "North Pole" (η)? Ancient Averaging. And Weights?

M1 In *GD* 1.24, Ptolemy twice attempts to design a planar portrayal of a broad spherical geographical segment, representing the known world — the *ekumene* — covering 180° of longitude from the Blest Isles (0° longitude) to easternmost China-Vietnam (180°E. longitude)[48] and 79°5/12 (*GD* 1.10.1) of latitude from Thule [Shetlands (Mainland)] (63°N. latitude) to anti-Meroë (16°5/12 S. latitude, a parallel as far south of the Equator as Meroë is north of the Equator). It is the 1st of his two projections (*GD* 1.24.1-9) which will concern us, since it involves a hitherto-unsolved mystery. This projection (page opposite: Figure 1) is a fan, opened slightly more than a right angle: c.98° (§N11). Thus, all north-latitude *ekumene* semi-circles are represented by 98° arcs. (Versus fn 51.) The fan is fairly neatly placed within a rectangle about twice (fn 55) as wide as high, as we see from Fig.1, where the four corners of the rectangle are (clockwise from upper left) points α, β, δ, γ.

M2 For the 1st Projection's conversion of the spherical-segment *ekumene* to planarity, the degree-distance $T = 63°$ from Equator to Thule is made (§M4) into $T = 63$ linear units; likewise for the $S = 16°5/12$ from Equator to anti-Meroë, etc. In Fig.1, representations of several latitude-semi-circles are depicted as Ptolemy's source intended (fn 54):
the Thule semi-circle (latitude 63°N) = ξ-o-π;
the Rhodos (§M6) semi-circle (latitude 36°N) = θ-κ-λ;
the semiEquator (latitude 0°) = ρ-σ-τ;
the anti-Meroë semi-circle (latitude 16°5/12 S) = μ-ζ-ν.
(Repeating §M1: though each arc in Fig.1 is only c.98°, it represents 180° of longitude in the Ptolemy world-projection.)

M3 Beyond the Equator, instead of continuing to extend the radiating meridians of his fan-projection, Ptolemy decides to bend all meridians inward — resulting in the oddly-shaped, dark-bounded *ekumene* of Fig.1. This kink-step enables Ptolemy to force (*GD* 1.24.7) the length of the anti-Meroë parallel (south of the Equator: latitude −16°5/12) to be exactly[49] as long as its northern equivalent, the Meroë parallel (latitude +16°5/12).

M4 Ptolemy's angular↔linear duality here is effected by two rough expedients:
[a] Defining the fan's units by forcing the distance T from Equator to Thule circle — 63 *degrees of latitude* — to be 63 *units of space*.
($T = 63$ is henceforth both a distance and an angle-in-degrees.)
[b] Making the distance H, from the Thule circle to the fan's pseudo-N.Pole (point η in Fig.1) proportional to cos 63° — i.e., equal to cos 63° in units of R, the fan's radius from "N.Pole" (point η) to Equator. Simply put:

$$\frac{H}{R} = \cos\ 63° \tag{4}$$

These conditions produce $T = R - H = R - R\cos T = R(1 - \cos T)$. Thus:

$$R = \frac{T}{1 - \cos T} = \frac{63}{1 - \cos 63°} \doteq 115.38\ldots \approx 115 \tag{5}$$

(The rounding is Ptolemy's.) Which produces the radius H of the Thule latitude-circle (centered at the pseudo-N.Pole η):

$$H = R - T = 115 - 63 = 52 \tag{6}$$

[48] Ptolemy rightly scaled-down (§L3) Marinos' eastern limit from c.225° (15^h = 5/8 of circle) to 180° (12^h = 1/2 of circle); southern limit, from c.24° (Tropic of Capricorn) to 16°5/12 (anti-Meroë).

[49] This length-fidelity (perfectly reflected in our Fig.1 — and creating the absolute magnitude in eq.8) renders all other southern parallels of the *GD ekumene* virtually equivalent (in length, though not radius) to their northern counterparts.

Letting S = the south latitude of anti-Meroë, Ptolemy further defines

$$E = R + S = 115 + 16\ 5/12 = 131\ 5/12 \qquad (7)$$

This establishes all the fan's dimensions.[50] We next turn to the more puzzling question of how wide-open the fan will be.

M5 The openness of the fan is immediately determined when Ptolemy states (*GD* 1.24.2) that he will choose a vertical strut $Y = 34$ units, extending from ϵ (the top of the rectangle bounding the fan) to the pseudo-N.Pole η, which is the fan's radiating center. And then — a very strange step appears.

M6 Since Ptolemy follows Hipparchos and (*GD* 1.20.5) Marinos in taking the Rhodos latitude (36°) or klima ($14^{h}1/2$) as canonical for the mid-*ekumene*, he chooses (*GD* 1.24.3) the Rhodos parallel at latitude 36°N as the one along which he will (allegedly) adjust longitudinal distances precisely, just so that this parallel's curved length (***west→east*** arc) has the correct proportion (4:5 $\approx \cos 36°$: *GD* 1.20.5 & 24.3) to the fan's already-determined ***north→south*** radial distances (§M4).

M7 That step is odd because, when he earlier (§M5) established $Y = 34$ units, this rigidly fixed the fan's openness, and thus the proportion along the Rhodos parallel — i.e., ***there is no fan-openness flexibility left***, once Y is set at 34 units.

M8 Well, you may suppose: Ptolemy must have chosen $Y = 34$ with this very point in mind — this of course has to be the precise value for Y which will ensure proper Rhodos-parallel proportionality. But, no. He didn't, and it isn't. We can tell so by just doing the math.

M9 If we let L be the latitude of Rhodos or any other place, the following equation finds that value of Y which will guarantee the desired proportionality at the given L's parallel:

$$Y = H \cos \frac{16200 \cos L}{\pi(R - |L|)} \qquad (8)$$

(L's sign-insensitivity in this equation is due to Ptolemy's kink-step: §M3.)

M10 But the truth swiftly reveals itself when we substitute Rhodos' L (36°) into this equation: we get $Y \doteq 31$ units[51] (nearly 32 without Ptolemy's eq.5 rounding) — not 34 units. But $Y = 31$ corresponds to fan-spread 106° (not the 98° of §M1), since

$$F = \text{Fan-Spread} = 2 \arccos(Y/H) = 32400 \cos L/[\pi(R - L)] \qquad (9)$$

so for $L = 36°$, $F = 32400 \cos 36°/79\pi \doteq 106°$.

[50] A list for ready reference. If we go up the mid-vertical of Fig.1, we find:
o-η is of length $H = 52$ (as is ξ-η);
σ-o is of length $T = 63$ (as is ρ-ξ);
σ-η is of length $R = 115$ (as is ρ-η);
ζ-σ is of length $S = 16\ 5/12$ (as is μ-ρ);
ζ-η is of length $E = 131\ 5/12$ (as is μ-η).
We recall that ϵ-η is of length Y. Note that ζ-ϵ is of length Z (§N3), as are the sides of the 2-1 rectangle: γ-α & δ-β; also equal to Z are: α-ϵ, ϵ-β, γ-ζ, ζ-δ.

[51] This accounts for the non-fitting & unintended aggravation that points ξ & π lie above the top (α-β) of the rectangle in several modern depictions of the situation. (The discrepancy has long been recognized; see, e.g., Wilberg & Grashof 1838-1845 p.78.) The screwup is not by the drafters but by Ptolemy, who did not realize (§M12) that $Y = 34$ units is not for the Rhodos parallel (corresponding via eq.9 to the 106° fan-spread used by the non-fitting diagrams just cited) but was designed as an average fit (§M14) to all *ekumene* parallels. Note that for $L = 0°$ (Equator) or 63° (Thule), fan-spread would be 90° ($Y \doteq 37$). The average of 106° & 90° is 98°, which fits $Y = 34$ (the average of 31&37: §M13).

M11 Two obvious questions now arise:
[a] Why didn't Ptolemy know the origin of $Y = 34$?
[b] What, then, is the true origin of his choice (§M5) of $Y = 34$?

M12 The answers are:
[a] Because as usual Ptolemy plagiarized (fn 45) math he didn't understand the origin of.
[b] We get a clue to the actual origin when we substitute other latitudes L into the foregoing equation: we find that Y reaches a minimum very near Rhodos — and is considerably higher near the Tropics or the Arctic. The Y for Thule ($L = T = 63°$) is the same as for the Equator ($L = 0°$), since substituting either of these two L-values into the general equation (eq.8) reduces it to:

$$Y = H \cos[16200/(\pi R)] \doteq 37 \qquad (10)$$

M13 Noting that the mean of our last two results is (31 + 37)/2 = 34, we may now commence our solution-reconstruction (§M14) of the insights of the actual designer of the fan-map Ptolemy swiped.

M14 The 1st thing the true originator presumably noticed was that, in order to arrive at a meaningful averaged Y-value, it made no sense to use (as Ptolemy claims to: §M6) a mid-*ekumene* parallel (Rhodos: §A2) — since the solutions for Y did not increase linearly or even monotonically in the latitude-range under consideration. Instead, if we go south: the values for the Y that are apt (i.e., produce correct longitudinal proportion: §M6) start at $Y \approx 37$ for Thule, dip to a minimum of about 31 almost exactly at Rhodos, and then double right back up to 37 for the Equator. So the obvious crude solution was to average 31 and 37, yielding 34.

M15 Better: a mean Y for all *ekumene* latitudes also = 34. With or without eq.5 rounding. If we go on to a truly proper solution and use weightings by area (since tropical latitude-intervals contain more area than non-tropical), we still find that mean $Y \doteq 34$. (Again: with or without rounding.)[52] I.e., the result is a firm one, encouraging the hypothesis that we have here successfully induced the true origin of Ptolemy's strut-length: $Y = 34$, an origin of which he was (§M14) evidently unaware. Moreover, the result is consistent with (though it does not prove) ancient mathematical mappers' competent attention to proportional preservation of areas (even if but imperfectly), a consideration for which no evidence has previously been in hand.[53]

[52] If we eliminate the southern latitudes, we yet find $Y \doteq 34$, except for the non-weighted average with rounding, where $Y \doteq 33\ 1/3$ instead.

[53] See, e.g., B&J p.38.

N Impossible Dream: Symmetric-Rectangle-Bounded *Ekumene* Fan

N1 There is an attractive alternate theory of the origin of $Y = 34$: the suggestion (§N6) that the 2-1 rectangle (§M1) bounding Ptolemy's *ekumene* influenced the openness of the fan (Fig.1): "The length of 34 units . . . seems to have been empirically chosen to accommodate the largest map in the given [2-1] rectangle without truncation of the corners [ρ&τ]." (B&J p.86 n.68.) We will now explore this theory, which takes us in a very different (but equally fascinating) direction from the previous section, §M.

N2 Ptolemy says his projection nearly (§N6) fits neatly into a 2-1 landscape-oriented rectangle: see Fig.1.

Since the fan-projection is symmetric about the mid-vertical (ϵ-ζ), the rectangular condition can be equated with fitting the left or right half of the *ekumene* into a split-off square. (Splitting the rectangle into halves, we will use the left square during the following analysis). Fitting the half-*ekumene* into a square will henceforth be referred to here as: the split-constraint or just The Split.

N3 Having arranged that each half of Fig.1's rectangular bound is a perfect square[54] of side Z (fn 50), we take half of the horizontal straight line between ρ & τ and call it B. Note: if The Split-condition is met, then B should equal half of the rectangle's top border (α-β). But it obviously does not, for reasons to be seen: §N7.

Our aim is to (as closely as possible: §N21) meet the Split-condition, which can be expressed simply as:

$$Z = B \tag{11}$$

N4 We then search for the value of Y which ensures that Ptolemy's *ekumene*-fan will satisfy The Split. The equation is (using the inputs already defined):

$$Y = \frac{E + (R/H)\sqrt{R^2 + H^2 - E^2}}{(R/H)^2 + 1} \tag{12}$$

N5 Ptolemy starts (§M5) by assuming that the meridian-radiating center of the fan (the pseudo-N.pole: point η in Fig.1) is $Y = 34$ units (*GD* 1.24.2) above the top of the rectangle that he proposes to contain his *ekumene* projection. (To repeat, we are saying that in Fig.1 the distance from η to $\epsilon = 34$ units.)

[54] Notice to those checking-via-ruler the rectangle of the Nobbe 1843-5 p.47 illustration of Ptolemy's 1st projection (reproduced at www.dioi.org/gad.htm#nobm, with the *ekumene* bounded in green): its halves are accidentally drawn not quite square, though very close. Also, many modern diagrams have failed along the anti-Meroë parallel. Creditable exceptions are those of Wilberg & Grashof 1838-1845 Fig.8 [p.96c2], B&J p.36, S&G 1:122-123, 2:748-749. The present illustration (our Fig.1) is perhaps the 1st rigorously accurate illustration of the anonymous ancient cartographer's full intended map-rectangle concept. (Where compatible choice of $Y = 34$ and fan-spread 98° allows meaned area-proportionality while ξ & π lie on line α-β: §§M14-M15.) Fig.1 is designed in pure Postscript (as was ‡1's Fig.1).

N6 Ptolemy admits (*GD* 1.24.1) that his 2-1 rectangle isn't quite exact (§N2): the rectangle's width is only nearly [εγγιστα] two-fold[55] its width. But: why only *approximately* twice as wide? Why not adjust Y such as to make the ratio exact? — since the priority here is suspected (§N10) to be The Split: a symmetric 2-1 rectangularly-bounded fan, for reasons either aesthetic (symmetry) or practical. (A portable map that is conveniently square after one protective fold?)

N7 The hitherto-unrecognized answer is that, given Ptolemy's specs for the projection's essentials ($T = 63$ and $S = 16$ 5/12), the 2-1 rectangle-bound condition (§N2) for the fan cannot be met. Mathematically speaking: for the cited Ptolemaic values of T&S, the only solutions for Y that can result from eq.12 are not real. This surprise finding will now lead us onto unexpected paths.

N8 I.e., the *ekumene*-fan as Ptolemy ultimately constructed it cannot fit into a 2-1 rectangle, no matter how widely or narrowly the Thule-bounded *ekumene*-fan is fanned out, so long as $S = 16$ 5/12. Try it for yourself. As S is increased, we find (from eq.12) that the maximum *ekumene* southern-limit S that allows $Y = 34$ and satisfies the symmetry of The Split is about $S = 6$.

[55] For the 2nd projection, there is no such qualifier (*GD* 1.24.17), even though there might as well have been — since for both projections the 2-1 rectangular bound is slightly wider than necessary. But for the 2nd projection, there is no appearance that an adjustment might render the *ekumene* exactly twice as wide as high. Its definition is quite different from the 1st, and results in a fan opened only about 61° (vs the 1st projection's 98°: §M1), with a pseudo-north-pole c.180 units above the Equator (vs the 1st's 115 units: eq.5).

N9 When the Fan Fit The Split
So the 2-1 theory has exploded in disaster: ***no choice*** of Y will satisfy Ptolemy's $S = 16\,5/12$ and allow the fan-projection to fit the symmetric 2-1 rectangle. Indeed, the maximum S that will permit satisfaction of The Split (for *any* choice of Y) is found via the equation:

$$S_{\text{max}} = T\frac{\sqrt{1+\cos^2 T}-1}{1-\cos T} \tag{13}$$

which for $T = 63$ (fan's north bound at Thule) yields $S_{\text{max}} \doteq 11$ 1/3.
N10 Things get even more intriguing if we assume (as some non-adamantly have: §N1) that $Y = 34$ was an empirical adjustment to The Split (the 2-1 rectangle condition: eq.11). We can test the theory by finding (§N21) the value of Y which *best* satisfies The Split. Answer: $Y \doteq 21$ — a value not even close to 34.
$Y \doteq 21$ satisfies The Split to within 5%: that is, $Z/B < 1.05$. But Ptolemy's $Y = 34$ cannot satisfy the 2-1 rectangle condition to better than 11%, i.e., $Z/B > 1.11$.
N11 However, let's keep exploring the theory that the 34 was chosen for The Split. (If Ptolemy was seeking any other type of symmetry, the obvious and nearby alternative would have been to make the fan-spread angle [ξ-η-π] equal to exactly 90° — not the seemingly pointless and peculiar [roughly 98°] spread we actually find: see fn 55 or Fig.1.) A 90° spread would make all longitude slices neatly 1/2 their real angular thickness.[56]
N12 Our math for an attempted Split-inspired reconstruction of the process behind $Y = 34$ will, up to a point, be the same as Ptolemy's — only simpler.
We round $R = 115.4$ to 115 (just as in eq.5 or *GD* 1.24.4) but then use a simple fan — i.e., *without*[57] Ptolemy's equatorial kink.
N13 Once we dispense with Ptolemy's clever kinky-projection scheme, we may easily find the S that produces $Y = 34$:

$$S = H^2\frac{\sqrt{1-(Y/H)^2}+1}{Y} - R \tag{14}$$

Substituting Ptolemy's values, $Y = 34$ (§M5 or *GD* 1.24.2) and $R = 115$ & $H = 52$ (eqs.5&6 or *GD* 1.24.4), we find:

$$S = 24.7 \tag{15}$$

A provocative result, since that is virtually right on the southern tropic (24°).
N14 However, as noted: $S = 24°$ is Marinos' value — according to Ptolemy himself (*GD* 1.7.1-2 & 9.6). Thus, we have found a potentially fruitful alterate-possibility for the source of the problematic $Y = 34$: a non-kinked fan-*ekumene*, with Marinos' latitudinal breadth of the known world, though Marinos is said (§N17) not to have used a fan-projection.
N15 Having thus found an S that could have led to *GD* 1.24.2's $Y = 34$, we may simply invert the process to follow in the hypothetical math-footsteps of the hypothetical ancient scholar who hypothetically deduced said Y. If we also dispense with intermediate variables, to show dependence purely upon the *ekumene*'s northern & southern limits (T & S, resp), the inverse of the previous equation gives us what we need:

$$Y = 2\frac{S + T/(1-\cos T)}{1+[\frac{1+S[1-\cos T]/T}{\cos T}]^2} \tag{16}$$

[56] The corresponding $Y = H/\sqrt{2} = 37$, obviously not Ptolemy's choice.
[57] That is, we do not immediately follow Ptolemy in suddenly bending all meridians inward after southward-crossing the Equator. That step eliminated (for Ptolemy: §M3) the extreme-outside points μ&ν. But we instead (§N13) keep it simple by letting lines η-ρ and η-τ in Fig.1 extend right straight out to μ and ν, respectively — and leave them be (i.e., no kink) — just as these two points are shown (slightly outside the 2-1 rectangle in Fig.1).

N16 Substituting (into the above equation) $T = 63$ (Thule) and $S = 24$ (southern tropic), the hypothetical ancient computer (of the Y that has come through to us) found

$$Y = 34 \tag{17}$$

(Barely less than 34 1/2 without Ptolemy's rounding [eq.5] of R to 115; or about 34 1/8, if that rounding is adopted.)
N17 But *GD* 1.24.4-5 denies that Marinos used the fan-scheme. If this report is to be trusted and if the Split-hypothesis is valid, then: at an early stage in the history of the development of the fan-approach, a scholar (working sometime between Marinos and the final version of *GD* 1.24) tried out a simple (no-kink) fan using Marinos' southern limit ($S = 24$).
N18 However, had he adopted $S = 16$ 5/12 without[58] kinking his projection, he could easily have found (using eq.16) that for this case the appropriate $Y = 36$, which would in fact effect a perfect-Split circumscription of the (non-kinked) fan by the preferred symmetric 2-1 rectangle.
N19 So, if the Split-theory is valid, Y must have been frozen at 34 before any steps were taken to abandon either
[1] assumption of $S = 24$ (Marinos: fn 48), or
[2] the simple non-kinked fan-scheme.
N20 If Ptolemy adopted $Y = 16$ 5/12 before kinking his fan, then he could easily have arrived at $Y = 36$ by the same means that 34 was arrived at. (As already shown above: §N18.) Since 36 is not what survived, it would follow that Ptolemy instead kinked his fan before bringing his southern boundary from $Y = 24$ up to 16 5/12.
N21 However, either way, he at some point would be faced with the problem of finding out what Y would most closely effect The Split if the kinked version of his *ekumene* projection were adopted. For this search, he had best be aware that the eq.11 Split-ratio (Z/B) is extremal when (on Fig.1) a line drawn from ζ to ξ is perpendicular to the radial line η-μ. Thus, the best fit to The Split occurs when:

$$Y = \frac{H^2}{E} \tag{18}$$

For $S = 16$ 5/12, this equation yields, as noted previously (§N10), $Y \doteq 21$, which corresponds (eq.9) to fan-spread 132°. For $S = 24$, $Y \doteq 20$ — corresponding to fan-spread $F = 135°$.
N22 Even if the foregoing Split-theory isn't historical (and the prior §M development — much-preferred by DR — obviously assumes that it is not), the mathematical development of it here has been thoroughly enjoyable.

[58] B&J p.87 n.69 point out the oddity that the *GD* 1.24 discussion refers only to pt.υ not pt.ζ, though they are identical. (Both are shown in Fig.1.) This would appear to indicate that at some drafting point, before arrival at the final version of the first projection, pts.υ&ζ were separate. This could have happened during experiments ere the kink (when the 2-1 rectangle touched pts.μ&ν) or ones where the projection's southern parallel was the Equator (§I2) or the Tropic of Capricorn (fn 48).

References

Almajest. Compiled Ptolemy c.160 AD. Eds: Manitius 1912-3; Toomer 1984.
B&J = J.L.Berggren & A.Jones 2000. *Ptolemy's Geography*, Princeton.
Aubrey Diller 1934. Klio *27*:258.
Aubrey Diller 1984. *GD* Book 8, DIO *5*.
Dennis Duke 2002C. DIO *12*:28.
GD = *Geographical Directory*. Ptolemy c.160 AD. B&J. Complete eds: Nobbe; S&G.
Handy Tables. Compiled Ptol c.170 AD. Eds: Halma 1822, Heiberg 1907, Tihon 1971f.
Hipparchos. *Commentary on Aratos & Eudoxos* c.130 BC. Ed: Manitius, Leipzig 1894.
Ernst Honigmann 1929. *Sieben Klimata und die* Πολεις Επισημοι, Heidelberg U.
Karl Manitius 1912-3, Ed. *Handbuch der Astronomie* [*Almajest*], Leipzig.
C.Müller 1883&1901. *Claudii Ptolemæi Geographia*, Paris. (Bks.1-5 of *GD*, plus maps.)
O.Neugebauer 1975. *History of Ancient Mathematical Astronomy* (*HAMA*), NYC.
C.Nobbe 1843-5. *Claudii Ptolemaii Geographia*, Leipzig. Repr 1966, pref A.Diller. Keith Pickering 2002A. DIO *12*:3. D.Rawlins 1982G. Isis *73*:259.
D.Rawlins 1982N. ArchiveHistExactSci *26*:211.
D.Rawlins 1985G. Vistas in Astronomy *28*:255.
D.Rawlins 1985H. BullAmerAstronSoc *17*:583.
D.Rawlins 1991H. DIO *1.1* ‡6.
D.Rawlins 1991W. DIO-J.HA *1.2-3* ‡9.
D.Rawlins 1994L. DIO *4.1* ‡3.
D.Rawlins 1996C. DIO-J.HA *6.1* ‡1.
D.Rawlins 1999. DIO *9.1* ‡3. (Accepted JHA 1981, but suppressed by livid M.Hoskin.)
D.Rawlins 2002A. DIO *11.1* ‡1.
D.Rawlins 2002B. DIO *11.1* ‡2.
D.Rawlins 2003J. DIO *11.2* ‡4.
D.Rawlins 2002V. DIO *11.3* ‡6.
D.Rawlins & K.Pickering 2001. Nature *412*:699.
Louis Renou 1925. *La Géographie de Ptolémée: l'Inde*, Paris. (Bk.7.1-4.)
Paul Schnabel 1930. SitzbPreussAkadWiss, Berlin (phil-hist) *14*:214.
Strabo. *Geography* c.20 AD. Ed: Horace Jones, LCL 1917-1932.
S&G = A.Stückelberger & G.Graßhoff 2006. *Ptolemaios Handbuch Geographie*, U.Bern.
Tacitus. *Histories* c.100 AD. Ed:Clifford Moore, LCL 1925-31.
C.Taisbak 1974. Centaurus *18*:253.
Hugh Thurston 1998. DIO *8.1* ‡1.
Gerald Toomer 1984, Ed. *Ptolemy's Almagest*, NYC.
Friedrich Wilberg & Carl Grashof 1838-1845. *Claudii Ptolemæi Geogr*, Essen. (Bks.1-6.)

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