‡1 Hipparchos' Eclipse-Based Star Longitudes: Spica & Regulus

His 3 Worst Ref-Star Longitudes & 3 Eclipses ⇒ 3 Neat Fits

2nd Century BC Spherical Trig, But No Equation of Time

Muffioso Toomer's Hipparchan Lunar Distance Verified

Muffia-J.H.A. Pb-Papers Reincarnate Ancient Muff

Classic Coherent Historical-Theory Fruitfulness

A Klan-Klod-Klue

A1 Among the numerous[1] gymnastic hysterical-astronomy pratfalls enlivening *JHA*'s hefty (64 pp) James Evans 1987 double-lead-paper attack[2] upon (then-minority) Ptolemy-doubters was [*JHA* Editor-to-be] Evans' lordly illustration of their dumb overestimation of ancient ocular accuracy. To illustrate his point Evans 1987 n.50 (p.275) presents his own non-telescopic (cross-staff) 1981/7/16 Seattle observational determination of the longitude of a star (λ Sgr) by using a lunar eclipse (as Hipparchos had) — which after Evans' reduction produced a longitude erroneous by $-2^\circ/3$, thus according to him (*idem*) showing that the huge errors in some ancient observations were so ordinary that such were a poor basis for learning anything about ancient science. As further examples, Evans specifically mentions (*idem* & p.235) Hipparchos' two hugely disparate Spica data (explained below: §B) which disagree by over 1°. He then draws for us a Muffiose lesson (emph added): "***No better demonstration could be wished*** of the uncertainty attached to the method" of fixing stars' longitudes by eclipses. However, when instructor Evans ***repeats the very same sermon*** (on Hipparchos' eclipse-star errors) 11^y later at Evans 1998 p.259 ("This shows the size of the possible errors in ancient measurements of absolute star longitudes"), he slyly deletes mention of his formerly prominent 1981 eclipse-star measures — which shows that (during the 1987-1998 interim) Evans had read Rawlins 1991W fn 288 (below: §A2) and therefore learned that DR had discovered that Evans' and Hipparchos' errors ***WERE NOT OF MEASUREMENT BUT OF BASIC SPHERICAL-ASTRONOMY MATHEMATICS*** (an embarrassment explained below at §A2). I.e., when ineducable educator Evans' 1^{st}-hand evidence somersaults, ***he just pretends he was right anyway***, unable to admit *DIO* scored & "premier" *JHA* bellyflopped: standard *JHA* honesty and inquiring empiricism. All of which sets up an irony whose fruitful blossoming is the present paper's main subject.

A2 As just noted: said irony's core was revealed[3] in Rawlins 1991W fn 288. Contra Evans, neither his own nor Hipparchos' problems were observational. Both simply mis-computed the reduction of valid observational data by using invalid math: the ***wrong sign*** for their parallax corrections. For the 1981 Evans case, at mid-eclipse, the longitudinal lunar parallax p_λ was virtually $1^\circ/3$. So Evans' sign-confusion created a huge net error because, whereas longitude parallax p_λ (the difference between topocentric [observer-centered: outdoor-visible] and geocentric [indoor-tabular] longitude: eq.2) is obviously supposed to be ADDED when converting a calculated geocentric lunar longitude into a topocentric (observer-centered) longitude, Evans instead SUBTRACTED it as if reducing

[1] See also *DIO 3* §L8 & fnn 95-97, and *DIO 4.1* ‡5 §A. Funnier yet: www.dioi.org/cot.htm#sckp.

[2] Typical of the modern Ptolemy salescorps, *JHA* Assoc.Ed Evans makes his attacks on DR only in captive arenas (safe there from reply or debate), while never citing any external source correcting his mis-science. Similar integrity: ‡3 fn 56. On error-admission fear: ‡4 §G2; www.dioi.org/mot.htm#jrgs.

[3] Rawlins 1991W's math has been verified in detail by Hugh Thurston and John Britton. We thank both for an arduous, specialized task.

an outdoor topocentric observation to find geocentric longitude. Thus the sign mixup would naturally cause an error of about $-2^\circ/3$ or $-40'$ — and the laughably impossible "observational" longitude he reports is indeed (Evans 1987 p.275 n.50): "too small by about $40'$ ". (Typically, Evans has had no comment since, despite DR [South Bend, IN, 1997 June, face-to-face] and Hugh Thurston [by letter] gently bringing the matter to his attention.)[4] After correcting for this Muff, we can verify the admirable smallness of the 1981 observational error of Evans (a dedicated student of ancient instruments and possessor of a steady hand, since the cross-staff requires it): merely one or two arcmin — just the sort of accuracy DR has consistently[5] ascribed to the best ancient naked-eye observations.

A3 Only a scholar catering to modern Hist.astron's cult-klan could straightfacedly propose that an error of magnitude $2^\circ/3$ — nearly *triple* the lunar semi-diameter — is observational and so by implication helps excuse the tight adherence of Ptolemy's "observations" to indoor-calculations (i.e., frauds) while disagreeing hugely with the outdoor sky.

A4 Note that a major member of Ptolemy's faked "observations" (*Almajest* 5.12-13) is also off by $2^\circ/3$. (See discussion at R.Newton 1977 pp.182-191. Also *DIO 8* ‡1 fn 13.) Scribbling a drawing will give one an idea of how ridiculous this is: mislocating a disk so grossly that the real and theoretical disks ($1^\circ/2$ wide in these lunar cases) don't even come close to *overlapping*,[6] the very feat Evans misclaimed he'd personally achieved in 1981 and is now too embarrassed and too steeped in Muffia academic integrity[7] to retract.

A5 NB: After the three-fold (§A6) [now **four-fold** (§F3)] collapse of Evans' implicit alibis (Hipparchos' eclipse-stars & his own: §A1) for Ptolemy's huge "observational" errors, ***the Muffia of course hasn't abandoned its support*** [see §A1 sermon] ***for the same-old Ptolemy-worship the alibis were designed for***. (Which figures, since evidence has little relation to that cult's belief-system.) It hasn't occurred to Muffiosi (whose strong points don't include philosophy of science) to ponder a simple question: if devotion to our favorite positions keeps leading us into embarrassing crackpot-level muffs (e.g., §A1 & *DIO 2.3* ‡8 §§C10-C15), does this not suggest that said positions are less than completely secure?[8]

[4] Both inquirers were told by Evans that he would look into it. But he never communicated what he found. Except by implication: the deft Evans text-surgery cited at §A1 & fn 7.

[5] E.g., Rawlins 1982G p.263 & n.17, Rawlins 1985G *passim*, & Rawlins 1985H.

[6] Also true of all four of Ptolemy's *Almajest* 3.1&7 solar equinox-solstice "observations" of the Sun, which agree 50 times better (Rawlins 1987 p.236) with his indoor tables than with the actual outdoor Sun. See Thurston on R.Newton at *DIO 8* ‡1 §A.

[7] Evans 1987 n.50's misadmonishment (§A1) is repeated in his later book: Evans 1998 pp.256-259; but this (post-*DIO 1.3* fn 288) Spica sermon quietly avoids discussion of his Seattle observation of the 1981/7/16 eclipse in this connexion (just photo at p.48, 100s of pages distant from his Hipparchos-Spica comments), shifting attention instead to the previously unadduced eclipse of 1977/4/3-4, seen from Spokane. (Why must Evans go back 21^y for a "recent" [*ibid* p.256] eclipse [mildly reminiscent of a Ptolemy ploy: www.dioi.org/cot.htm#cknh], considering that Evans 1987 went back merely 6^y to find a usable eclipse? Implication: 1977 is ere 1981, and JE here has his signmanship OK at last, so: *seeeee*, he knew how to do it all along. The catch: unlike at Evans 1987 n.50, no 1977 data are reported as outdoor-measured by Evans, though he repeatedly [Evans 1998 pp.256-257] speaks of "observations" or "observed".) So he knows he screwed up the 1981 eclipse's parallax-sign, but CAN'T admit that (§A2) *DIO* corrected it for him. (Note contrast to, e.g., *DIO 2.1* ‡4 fn 18 & *DIO 11.2* cover.) Or admit the falsity of his alibi-for-silence-on-errors pretense (*DIO 9.1* p.2) of not reading *DIO*. (Had he faced reality on Regulus at Evans 1998 pp.259f, he could've made the present Regulus discovery himself. More wages of shunning.) For Evans' citation-practice integrity, see ‡3 fn 24. (NB: This chauvinist lawyer-for-Ptolemy [www.dioi.org/cot.htm#msmr&#gsfh & fff.htm#gckp] is heirhead-apparent to the *JHA*'s M.Hoskin, hist.astron's own Lord Sommers [*DIO 2.3* ‡1 fn 18]. Who'll dispute the aptness?) Another corruptive consequence of a cult's living with the shame of knowing that its sacred mission (hyping derivative Babylonian astronomy & Ptolemy as original genius) is unadmittably indefensible.

[8] Indeed, Muffia desperation to reject non-cult common-sense has now reached the point where the clique has even (presumably unknowingly) brought in Velikovskian-circle expertise to denigrate RN-DR work. During my 1995/2/26 chat with B. van Dalen, he mentioned that the reason his (generally wonderful) paper van Dalen 1994's n.1 had cited the 1989 Fomenko *et al* paper (which, with Velikovskian boldness and correctness has re-dated the Ancient Star Catalog by ordmag a *millennium*) is that it showed that one could prove anything with statistics. (Is the Muffia aware that Fomenko believes that the *Almajest* is a late medieval document, and that the Nabonassar epoch [747 BC for most of us] is actually from the AD era? Full information available from the Velikovskians' least favorite mongoose, Leroy Ellenberger, 3929 Utah Str, St.Louis, MO 63116; phone 314-772-4286. See also the excellent *Isis* review of Fomenko's book. A central technical flaw undoing the entire Fomenko *et al* analysis is revealed in the 1995-added note in *DIO 4.3* ‡14.) Yes, one can prove anything with statistics — if the sample is biased or the math miscomputed. But it is up to the Muffia to show what relation such a truism has to statistical findings it loathes, e.g., Rawlins 1994L. Merely doubting statistical results in general is a pathetic pose. It should be added that two expert mathematicians (K.Pickering & H.Thurston) have already checked and verified in detail the math of the 1994 paper — a paper showing that Ptolemy not only stole the Catalog but clumsily attempted to hide this theft by the very method R.Newton 1977 had charged. Yet, Muffia publications — with their usual respect for academic decency & honesty — arrogantly continue to learn nothing from these results, in order that they may go right on profitably peddling their hero-plagiarist to the world as The Greatest of ancient astronomers. And such scholarship is published without a blush by centrist forums. Rarely does selectively-scattershot agnosticism scrape this low in the barrel. Rawlins 1982C's simple statistical proof (Tables IV&V) that the Star Catalog was stolen from Hipparchos by Muffia-hero C.Ptolemy, was similarly attacked (*JHA 23.3*:173-183; 1992/8) by Muffia capo N.Swerdlow, a disaster undercut by several freshman-level Swerdlow goofs (immediately revealed [1992/10] at *DIO-J.HA 2.3* ‡8 §C). Since that contretemps, a general Muffia ducking (even re-invention: www.dioi.org/det.htm#zmcg) of the whole field of statistics seems not only expected but downright inevitable.

A6 So much for the bad news. Now for the glad news: as on other occasions (Rawlins 1991W §§D1, O1, & S3), I have here become indebted to Muffia blundering for putting me onto a useful idea (though never so directly as in this gloriously delusional instance). For, Evans' §A1 sign-Muff quickly led me to wonder: could the same eclipse-parallax-sign-error *also* explain Hipparchos' most notorious empirical disaster (§B2)? — his grossly discrepant attempts to place the star Spica via two of the three lunar eclipses we know he observed. (If so [and we are about to see that this theory is indeed valid: eqs.6&7], then ***all three*** of Evans' ancient & modern sermon-star examples [§A1] — aimed at alibiing Ptolemy & showing up skeptic R.Newton's supposed naïveté about observational astronomy — are fallaciously adduced.) In Rawlins 1991W fn 288, it was remarked that the theory clicked. The following paper will provide (§B) for the 1st time full reconstructions of Hipparchos' math for these two Spica-misplacing eclipses, and then will go beyond, with an exploratory application (§E) to the only other extant Hipparchos eclipse, which we discover was used to position his hitherto-inexplicably ultra-misplaced fundamental star Regulus.

B Reconstructing Hipparchos' Eclipse-Placements of Spica & His Neglect of the Equation of Time

B1 Fundamental astronomers attempting to find fundamental stars' longitudes wrestled for centuries with an obvious inherent problem: 0° longitude is the Vernal Equinox, but that is the location of a solar event and the stars are invisible when the Sun is visible. The best-known pre-modern method was to use the Moon (or Venus) as a stepping stone: near sunset, find the arc between Sun and Moon while the former was still visible, then find the arc between star and Moon a little later (method nicely diagrammed by Evans 1987 p.235 Fig.4); finally, use mostly simple arithmetic (Rawlins 1982C App.B) to find the arc between star and Sun. But Hipparchos also applied an ingenious alternate method, which avoids such a rickety scheme: just measure how far a star is from the Moon at mid-eclipse, when the Moon is guaranteed to be virtually (though see fn 19) 180° from the Sun.

B2 Ptolemy tells us (*Almajest* 3.1) that Hipparchos used the eclipses of $-145/4/21$-22 and $-134/3/20$-21 to try locating Spica. The results: $173^\circ 1/2$ & $174^\circ 3/4$, resp, a terrible disagreement — over a degree! (Remember: the lunar semi-diameter is merely 1/4 degree.) So, we now apply the parallax-sign-error theory to both eclipses.

B3 For each eclipse, Hipparchos' method was:
[a] Measure by armillary astrolabe[9] the actual longitudinal difference $\Delta\lambda$ between the star, at longitude λ_a, and the mid-eclipse Moon at observed (topocentric) longitude λ'_M:

$$\Delta\lambda = \lambda_a - \lambda'_M \tag{1}$$

[b] Compute from his tables the longitudinal lunar parallax p_λ, which is the difference between λ'_M and the Moon's true (geocentric) longitude λ_M:

$$p_\lambda = \lambda'_M - \lambda_M \tag{2}$$

[c] ***Without applying the equation of time***, find via Hipparchos' PH theory[10] the Sun's true geocentric longitude λ_S at the time (according to Hipparchos' lunisolar theory) of mid-eclipse, which yields true geocentric λ_M by the simple equation:

$$\lambda_M = \lambda_S \pm 180^\circ \tag{3}$$

[d] Adding eq. 1 to eq. 2 and subtracting eq. 3 produces an equation for the desired stellar longitude λ_a:

$$\lambda_a = \lambda_S + p_\lambda + \Delta\lambda \pm 180^\circ \tag{4}$$

B4 If our theory is correct, Hipparchos mistakenly subtracted p_λ and thus found (instead of λ_a) an erroneous value which we will call λ_x (the "x" subscript signifying that this longitude is infected with wrong-sign parallax):

$$\lambda_x = \lambda_S - p_\lambda + \Delta\lambda \pm 180^\circ \tag{5}$$

B5 For the −145/4/21-22 eclipse: the outdoor longitude difference $\Delta\lambda$ (between Spica & the Moon) at the time when Hipparchos' indoor luni-solar theory predicted mid-eclipse (23:38 Lindos Mean Time),[11] was about $-33^\circ.8$, so he likely measured close to $\Delta\lambda = -33^\circ 5/6$. [b] Hipparchos' PH solar theory[12] placed the Sun at about $\lambda_S = 27^\circ 2/3$ at this time. (So geocentric $\lambda_M = 207^\circ 2/3$.) [c] The *Almajest* syzygial lunar theory puts the eclipsed Moon at $58^e.3$. (We define 1^e as one Earth-radius.) [d] For this distance at the Rhodos klima 36°N, the *Almajest* 2.13 parallax tables give $p_\lambda = +20'$. [e] So eq. 5 (which, recall, proposes using the wrong sign for p_λ) yields:[13]

$$\lambda_x = 27^\circ 2/3 - 1^\circ/3 + (-33^\circ 5/6) + 180^\circ = 173^\circ 1/2. \tag{6}$$

B6 For the time of −134/3/20-21 tabular mid-eclipse (just before 3^h), Hipparchos' outdoor measure of $\Delta\lambda$ would find close to $-2^\circ 3/4$. [b] Hipparchos' PH theory gives solar $\lambda_S = 357^\circ 1/4$. [c] The *Almajest* geocentric lunar distance is $64^e.9$. [d] Thus, for latitude 36°N, *Almajest* 2.13 $p_\lambda = -15'$. [e] So eq. 5 yields:

$$\lambda_x = 357^\circ 1/4 - (-1^\circ/4) + (-2^\circ 3/4) - 180^\circ = 174^\circ 3/4. \tag{7}$$

B7 We note that both results (eqs. 6&7) exactly equal the quite inaccurate (and even more grossly disparate) λ values reported at *Almajest* 3.1. (See §B2.)
B8 These matches strongly suggest the validity of the wrong-p_λ-sign hypothesis. They also offer other historical information, which we turn to next.

C The Hipparchos Lunar Model's Scale

C1 As we know (e.g., Rawlins 1991W eqs.23&24 and §R), Hipparchos used several different lunar distances throughout his career. If his mean distances assumed for the present parallactic computations differed drastically from c.60^e, this would affect p_λ inverse-proportionally. The fits attained here suggest that he or his computers used conventional values during the period of the present calculations. Which is consistent with our finding at fn 14.
C2 One can argue for nonpreliminary Hipparchan mean lunar distances of from 52^e to 67^e. (See Rawlins 1991W eqs.23-24 & §R1.) But use of these values instead of Ptolemy's (59 Earth radii: *Almajest* 5.13 & Toomer 1984 p.251 n.49) will affect eqs. 6-8 by only a very few arcmin. Nonetheless, though the present eclipse analyses (as well as fn 14) can work for 67^e, they won't for 52^e. A reasonable conclusion is that we here have come upon indications in favor of Gerald Toomer's finding (see, e.g., Toomer *loc cit*) that Ptolemy's 59^e lunar mean distance was that of Hipparchos.

D Hipparchos' Sph Trig Reconfirmed by His Parallax Corrections

D1 It has long been recognized (e.g., Neugebauer 1975 p.323) that parallax tables were in use in the 2nd century BC. (This was always obvious from *Almajest* 5.5, but perhaps no one has previously caught the implication for ***the onset of spherical trigonometry.***[14] Neugebauer *loc cit* explicitly contradicts it.) These tables were essentially the same as

[9] Hipparchos might read a slightly different result because of Earth-spin. The systematic errors of his Ancient Star Catalog indicate that he averaged 19^s of time-delay after setting the armillary astrolabe (by his reference-object) before getting the reading on his quarry-object. (See Rawlins 1991H §G4: 1/3 of $-13'$ is about $-4'$.) Whether the same error held during careful, repeated eclipse observations, we cannot be sure; but it makes little difference, given the rounding roughness of ancient data.

[10] See Rawlins 1991W §K10. PH theory's tables (possible tiny discrepancy suggested: *ibid* fn 199) at *Almajest* 3.2&6; λ_S was (similarly to the case of the Hipparchos lunar observations reported at *Almajest* 5.3&5) pre-computed for the tabular time of eclipse. The present results agree with Hipparchos' consistent neglect to apply the equation of time even to lunar data, as was earlier induced on quite independent grounds by Toomer, Jones, & DR. (Rawlins 1991W §§N1&N8. To repeat the note made there at the time: we thus have no evidence of the equation of time's use before Ptolemy.) This omission has a serious effect on calculations (lucky, allowing us to be sure of the eq.time's neglect), as do the $0^\circ.4$-amplitude & $0^\circ.2$-amplitude periodic errors of the Hipparchos-Ptolemy solar&lunisolar theories, resp. (Hipparchos worked by apparent time, though PH is for mean.)

[11] Hipparchos' likely location on the island of Rhodos (Rawlins 1994L §§F-G), near Lindos city: 36°08′N, 28°05′E. Keep in mind that in antiquity (in the absence of reliable mechanical clocks) most timekeeping was by Local Apparent Time, customarily via sundial. Hipparchos' clock-stars (Hipparchos *Comm* 3.5) would allow night timekeeping. But there is also the "moondial" possibility, especially easy while a lunar eclipse is proceeding: a sundial (or equivalent) could find pretty accurate time just by adding 12^h to the Moon's hour angle or (when moonlight was bright enough) to sundial-shadow position. The method is slightly corrupted by lunar parallax. For the −140 eclipse, the time-error would add $1'$ to the absolute magnitude of $\Delta\lambda$. (PH assumed for Lindos, not Alexandria.)

[12] See Rawlins 1991H §C6 for the standard *Almajest* 3 solar orbit which Hipparchos used during the period (§D5) which includes all three of the eclipses here discussed.

[13] We assume accurate observation and the ancients' common practice of rounding quantities to fractional degrees. Our fits here are almost too good (fn 22), which can be due to [a] Hipparchos having averaged a careful series of mid-eclipse data for each eclipse, and-or [b] DR having acquired Ptolemy's habit of favoring (postulating likely Hipparchan) roundings that lead to exact agreement. But the putative latter factor's net effect is trifling. [Rawlins 2018U §O realized Hipparchos' 1st Rhodos observation was the –146 S.Solst, 1st of the 3 cardinal-pt data he computed the PH orbit from, after his –145 Vernal Equinox, in time to predict mideclipse for his planned −145/4/21 Spica placement.]

[14] Toomer 1984 p.227 n.21 correctly points out the accuracy of Hipparchos' longitudinal parallax correction for the luni-solar observation he made on −126/5/2 at 6:20 Rhodos Apparent Time. (See also Neugebauer 1975 pp.92 & 323.) His correction was rightly positive (so he [or a member of his school] had by this late point in his career straightened out the signage of his procedure): $1^\circ/8 + 1^\circ/12$. (That is, $+12'1/2$, apt to a lunar distance of well over 60 Earth-radii.) The actual parallax was

those used by Ptolemy 3 centuries later. *Since parallax tables are contructed by spherical trigonometry, this finding confirms once again*[15] *the contention of Diller, van der Waerden,*[16] *Dicks 1994, and DIO that spherical trig throve in the 2nd century BC.*

D2 Note that *Ptolemy himself* indicates same through his suggestion (*Almajest* 3.1) that Hipparchos' Spica discrepancy may have been in his calculation of the parallax correction.

D3 The italicized §D1 point is utterly self-evident,[17] yet it has been missed by scores of prominent, well-paid professional historians-of-astronomy, each of whom has read the same passage dozens of times. And we may be sure that *JHA* & like establishment publications will not miss a beat in continuing to sanctify these same can't-see-nose-before-face archons — who, in Hist.astron circles, are the arbiters of accepted wisdom. And acceptable scholars.

D4 (Neglected, quite ambivalent hints that sph trig might be even older than Hipparchos are found at fn 16 & ‡3 §D5. Also Rawlins 1985G §8: 2nd table, the ancient data of which could actually be due to Ptolemy and thus not pre-Hipparchos.)

D5 It has been (Rawlins 1991H fn 7 & §C4 [& Rawlins 2018U *loc cit*]) theorized that the PH solar theory & tables were based upon observations of [–146 &] –145 and that his subsequent UH tables were based upon observations of −142/9 & −134/6 (thus could not be earlier than the latter date) — independently suggesting that Hipparchos' PH tables were used by him during the period −145/4/21-22 to −134/3/20-21.

E Sources of Error in Hipparchos' Placement of Regulus

E1 We now turn to the 3rd (and only other) eclipse known to have been observed & reported by Hipparchos — an eclipse which happens to have occurred *near the star Regulus*. Two initial comments: [i] Only 2 stars' explicit Hipparchos longitudes survive (*Almajest* 7.2): Regulus 119°5/6 and Spica 174°, **ideal fundamental stars, the nearest 1st magnitude stars to the ecliptic**. [ii] For Spica, the discrepant eclipse-based results he complains of (§§A6&B2) evidently (fn 22) induced him later to opt for placing this star instead[18] by conventional astrolabe technique (which was in fact more reliable than his mis-signed eclipse method); however, Regulus is the zodiacal bright star with the largest negative Hipparchos λ error for his Ancient Star Catalog's epoch (−126.28: Rawlins 1991H §F4): −35′. Rawlins 1991W (fn 147) remarked aloud at the enormity of this error (which led Ptolemy into a fraudulent copy of it: *DIO 8* ‡1 ⊙7), despairing as to whether its explanation would ever become known. (Another fruit of having at last the solution to the Regulus longitude mystery: Shevchenko 1990 had proposed that Hipparchos' Moon-star

about +1°/4, though that from Ptolemy's tables was +19′ for his ludicrous lunar distance of 43 Earth-radii. (The Neugebauer 1975 p.92 value [16′] is explicitly based upon Ptolemy's simple syzygial lunar model, not his final one.) Obviously, Hipparchos did not share Claudius Indoor Ptolemy's notorious belief that the Moon's angular size varied by a huge factor (of up to nearly two). Indeed, the smallness of Hipparchos' 12′1/2 parallax for the −126/5/2 observation indicates that his parallax calculations used a conventional lunar distance (as we already realized at §C1). We can check this by computing via modern theory the lunar parallax on the assumption that the geocentric lunar distance was 60 Earth-radii (vs 57 in reality): 14′; thus correcting Hipparchos' −126/5/2 observation of topocentric lunar longitude 351°2/3, we have 351°26′, for which the nearest Hipparchan approximation would be 351°3/8, which is just the Hipparchan geocentric longitude reported at *Almajest* 5.5 (Neugebauer 1975 p.92).

[15] See ‡3 Table 2 (or *DIO 5* Table 0, *DIO 4.2* [1994] p.56 Table 1).

[16] Rawlins 1985G n.9.

[17] We may get a glimpse of the inevitable escape routes (from this evidence) at A.Bowen & B.Goldstein *Amer Philos Soc Proc 135.2*:233 (1991) where triggish work is (automatically) ascribed (p.235) to arithmetic methods (an approach that has caused other amusing Muffia catastrophes: e.g., fn 15 & *DIO 1.2*); and ancient testimony regarding predecessors' technique is doubted (B&G n.5).

[18] If Hipparchos tried (assuming clear weather) confirming his Regulus longitude via the −131/1/17-18 eclipse (record not extant), the result would have been roughly 119°1/2, not discrepant enough (nothing like the enormous Spica −145 vs −134 clash) to cause his rejection of the −140 value in favor of an astrolabe-based result (as with Spica).

fundamental astronomy was in the evening, and Rawlins 1991W fn 138 had remarked on this proposal's redemption by Rawlins 1991H §G1. The only important exception seemed possibly to be Regulus. But the present results resolve the problem [indicating that Regulus alone among major Hipparchos-Ptolemy stars was not placed by astrolabe], so we may conclude that all the Hipparchos principal stars' astrolabe-based placements occurred in the evening, just after the Sun's setting, using a crescent Moon: Rawlins 1991H §G2.)

E2 Inductive detectives' highest ecstasy is the experience of coherent fruitfulness: when a theory already successful in one case is applied to an independent case and *the very same theory* comes up aces. (E.g., Jones & Duke at *DIO 11.2* [2003] cover & p.33; A.Diller's vindication below at ‡3 §E3; www.dioi.org/cem.htm#xidv.) Our outstanding mystery here is Regulus' perplexing Hipparchan super-misplacement (§E1), and our so-far successful theory is that eclipse-parallax-sign-error accounts for Hipparchos' horrible stellar longitude errors. If the theory is valid, can it also explain the *only other* attested (*Almajest* 7.2) Hipparchan stellar longitude, the very worst of the lot: Regulus?

E3 We now apply §B3's method — already good with both his two eclipse-based Spica observations (§§B5&B6) plus Evans' 1981 case — to Regulus & the nearby −140/1/27-28 eclipse (the *only* other Hipparchos-observed eclipse record we have: *Almajest* 6.5&9).

E4 For the −140/1/27-28 eclipse: [a] At tabular[19] mid-eclipse (22h), actual $\Delta\lambda$ was 5°07′, so (especially given his now-famous proclivity for integral[20] data), he likely expressed the measurement as exactly $\Delta\lambda = 5°$. [b] Hipparchos' PH theory gives λ_S = 305°09′ (*Almajest* 6.5 makes it 305°08′), so he would record $\lambda_M = 125°1/6$. [c] *Almajest* lunar theory distance = 54e3/4. [d] So for Rhodos, *Almajest* parallax tables, $p_\lambda = +29' \doteq 1°/2$ which would become −1°/2 after sign-mistake. [e] So eq. 5 yields, adding in 8′ (c. 1°/6) of Hipparchos-Ptolemy 1°/100y precession[21] (from −140 to catalog epoch −126.28):

$$\lambda_x = 305°1/6 - 1°/2 + (-5°) - 180° + 1°/6 = 119°5/6. \qquad (8)$$

E5 It is wonderful to find that this precisely[22] matches the egregiously erroneous (hitherto-unexplained) Ancient Star Catalog longitude for Regulus (119°5/6: §E1).

E6 Two curious historical notes in passing: [a] Regulus' λ was not used as a ref-star for astrolabe-placing the other Catalog stars of Leo, whose mean error at epoch was merely

[19] *Almajest* 6.5 just computes the time of mid-eclipse as 22:10 by finding when the Hipparchos-Ptolemy lunisolar tables have the true geocentric lunar longitude (125°08′ by the *Almajest* calculation) 180° different from the true solar longitude. But mid-eclipse accurately calculated (by one of Hipparchos' computers) from these tables would be nearer 22h. The difference (about −10m) is due to the c.5° tilt of the lunar motion vs the ecliptic in this partial eclipse, a factor that is even more trivial (−1m & −2m, resp) for the total −145 and −134 eclipses, where Hipparchos also likely rounded the tabular-predicted Lindos Apparent Times (to 23h2/3 and 3h, resp). If Hipparchos' presumed −140 use of 22h was not just a rounded value but due to accounting for tilt, then he made a tiny slip, since at the tabular mid-eclipse moment (22h) the Moon's longitude was about 5′ short of being opposite the Sun. (If Hipparchos actually used 22h1/6 Lindos App. Time: −5° would still be the likely recorded $\Delta\lambda$.)

[20] See, e.g., R.Newton 1977 pp.245f, Rawlins 1994L §E4, *DIO 10* [2000] fn 177.

[21] Hipparchos' −140 Regulus longitude would've been listed at 119°2/3. Though 8′ is something less than 1°/6, the Ancient Star Catalog's longitudes are almost exclusively expressed in units of 1°/6, so though precession to the Catalog's epoch yields 119°4/5, this would still end up being listed as 119°5/6, since nothing in the Catalog is expressed in degree-fifths.

[22] *DIO 8* ‡1 ⊙11 found that astrolabe lunisolar observations showed ±0°.1 consistency. Ancient Star Catalog longitudes' mean error is 22′ (R.Newton 1977 p.216), but stars brighter than 3rd magnitude used by pre-Ptolemy ancient astronomers for observations cited in the *Almajest* (dropping too-south Sco, and 2 quarter-degree ending stars: *DIO 2.3* ‡8 fn 20), are β Tau, α Gem, β Gem, γ Vir, α Vir, α Lib, δ Cap, whose longitudes' deviations from a zodiacal error-wave (melded from Rawlins 1991H §§F1-F2) of $-9' - 13' \sin(\lambda - 96°)$, show scatter ±0°.1, around an average of +0°.1.
[Note added 2017. For −145, −140, −134, +1987 eclipses, *JHA*'s view insists on longitude errors of, resp, −33′, −35′, +33′, −40′. Removing parallax-mis-signs, & defects in Hipparchos' PH solar theory: errors in outdoor-observed star-Moon gaps were, resp, −2′, +7′, +1′, +2′. (All 6 ancient results share in common the same trivial error, due to ΔT uncertainty, of ordmag 0°.1 for that era.)]

$-15'$ ($20'$ offset[23] from Regulus' error). [b] Hipparchos stayed with his -140 Regulus λ fixed by eclipse, even after -134 indication (via Spica) of the method's unreliability.
E7 Late Ptolemy works' use of Regulus as a foundation-point suggests that Hipparchos held Regulus as a pivotal star in his astronomy, which could help explain why his -140 measurement of its position was retained inviolate to the end of his career. And Ptolemy's.

F Evaluating Hipparchos & the Sign-Slip Theory

F1 We conclude that our parallax-sign-error theory has survived the §E2 fruitfulness test: 4 hits for 4 at-bats. But the traditional image of Hipparchos as among the greatest of ancient scholars survives less robustly. (See also Rawlins 1991W § N16&S.)
F2 A temperate conclusion is that Hipparchos was a vital promoter of astronomy in antiquity, if not quite the critical scientific figure he was once thought to have been. (Indeed, some of his attempts at improving basic astronomical parameters may have degraded them. See, e.g., Rawlins 1991W §S1.) He is today most famous for discovering precession, yet Rawlins 1999 shows that it was known to Aristarchos of Samos about 1 1/2 centuries earlier.
F3 But this doesn't dim our gratitude for his merits, e.g., [a] Grounded in empiricism.[24] [b] Developed nested calendar (Rawlins 2002A fnn 14&17) and durable luni-solar theory. [c] Likely invented the clever "circuli" scheme (‡3 §I1). [d] Determined accurate obliquity. [e] Took accurate solstices [*DIO 20* ‡2 Table 3]. [f] Oversaw creation of his ever-remembered Ancient Star Catalog, the oldest extant detailed compendium of the starry heavens. [g] [Draconitic ratio good to ordmag $0^s.1$ via $-1244/11/13$ eclipse: www.dioi.org/jb13.pdf.]

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[23] I have elsewhere (Rawlins 1991W fn 253) suggested that Hipparchos' stable of mathematicians sometimes operated independently of him. (Perhaps occasionally with eyes aroll.) The nonrelation of Regulus to Leo's Catalog stars hints at an instance of this.

[24] ***All 4 observations examined here (3 ancient & 1 modern), superficially in error by ordmag 1°, fit our parallax-sign-slip theory and so turn out to have been accurate to within a very few arcmin***. The accuracy of Hipparchos' draconitic month was a pinnacle of Greek empiricism: *DIO 11.1* ‡3.