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# NEWCOMB'S DATA ON ANCIENT ECLIPSES REVISITED[1]

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**SUMMARY: Relying on the Greek text related to Babylonian-Hellenic observations of lunar eclipses in Ptolemy's "Almagest" (Halma M., 1813) and by analysing some Arabian notes about solar and lunar eclipses – for which S.Newcomb found considerable deviations from the adopted theory – a re-analysis of his results and conclusions is herewith undertaken.**

**The results of ancient data revision are based on Newcomb's alternative presumption that these discrepancies are caused by one or more unknown long-term inequalities in the motion of the Moon.**

**A quantitative analysis of ancient eclipse observations unambiguously indicates that they definitely are not to be rejected, provided, of course, that they are interpreted in proper way.**

The importance and the role of the solar and lunar eclipses observed in the remote past are well known to everyone whose field of research is the theory of lunar motion, in particular the problem of the secular-acceleration in the lunar mean daily motion or the problem of nonuniformity and variations in the Earth's rotation. Unfortunately, the number of available observations of such kind, sufficiently reliable, is very scant.

Because of the lack of reliable information concerning the place where they were observed and the time when they occured, a justified omission of many solar eclipses is made (those registered in Chinese imperial annals, as well as about twenty originating from other sources, e. g. Chaldean, Greek-Roman, etc). Hence, the entire scientifically usable documentation from the Ancient Era and the Middle Ages has been reduced until recently to a few tens of solar and lunar eclipses only. However, not even they have been used completely.

Initially, following Halley's indication that the lunar mean motion was not uniform (Halley, 1695), in their attempts to determine the amount of these variations the investigators limited their choice chiefly to individual eclipses: among the Babylonian ones those from Ptolemy's Almagest and from among the Arabian ones to those contained in one collection from the end of IX and the beginning of X centuries, attributed to Ibn Junis.

In recent time, however, papers where in addition to the results of modern observations, those from the far past are also subjected to analyses have become rare. This is particularly true of the eclipses from the Almagest. They seem to have been completely rejected just as Ptolemy's concept itself of the geocentric world system. The reason for such a treatment is certainly the doubt concerning the credibility of the data on these eclipses arising much from accusations of some astronomers that Ptolemy altered the data taken from Hiparchos so as to obtain a good fit to his theory, but which are not justified and have not been proved.

However, it is not understandable why such opinion has been accepted without resistance and why nobody did wonder: what could have been the reasons inducing Ptolemy, a diligent Alexandrian archpriest and respectable thinker, to do something

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like this, when it is quite clear that in the background there was neither a prestige desire, nor any greed motives? It is well known that both Hipparchos and Ptolemy after him attempted only one thing, each of them in his own way, to explain the celestial phenomena as they are seen by a careful terrestrial observer!

It is true that Newcomb through an objective reasoning tried to refute such a negative treatment concerning Ptolemy's information and data because he was convinced that differences between Hipparchos' results and Ptolemy's ones given in Almagest could be a consequence of a misinterpretation. Among others he sais: "... It does not seem probable that one who had dishonestly altered the records in his possession would have thus frankly stated result of his alteration" (Newcomb, 1878).

In contrast to this, Fotheringham openly declares at one place: "... the lunar eclipses are mainly quoted through the medium of Hipparchos, and, as they are regularly expressed in equinoctial time, had probably undergone some reductions before the form in which they are given in the "Almagest" was obtained. The one eclipse of which a cuneiform record has come down to us (that of the year 522 B.C. July 16) was certainly very loosely reduced, and I should prefer to reject the whole of the Babylonian eclipses..." (Fotheringham, 1915a; see the note following Table I).

In his paper published soon afterwards Fotheringham (1915b) did reject the Babylonian observations completlly adding that the difficulties following the interpretation of the times communicated for eclipses No 7-9 of Newcomb's list gave rise to think that these observations were not originating from Babylon.

In the following period of almost half of a century, the attitude of the researchers depended largely on the personal confidence in the authority of those advocating one of the two concepts concerning the value and importance of Ptolemy's inheritance (De Sitter, 1929; Brouwer, 1954; etc).

Fifteen years ago Stephenson and Morrison published a paper devoted to the study of long-period changes in the Earth's rotation (Stephenson and Morrison, 1984). The paper is characterized by a vast observational material arousing a particular attention by its contents of many ancient, Babylonian eclipses. According to the authors, these observations were discovered due to a new translation of the texts written on tablets, often in fragments, collected in the British Museum in London. In addition, it was emphasized that the texts were monthly "astronomical diaries" bearing on various celestial phenomena and their semiannual "lists" are given. However, no mention concerning the Almagest eclipses appears. On the plots presented in the paper the three earliest ones from the New-Babylonian-Empire period (VIII century B. C.) are not given, nor the three others observed by Ptolemy in Alexandria. Based on this and, especially, from the authors' remark in the Introduction one can conclude that they also are not confident as to the reliability (accuracy) of the data concerning these eclipses and that because of this they omitted them on purpose.

On the other hand, namely for this reason, a new question arises: have all the eclipses adduced and used by the authors really been observed phenomena and not partly results of predictions only?

This question is justified for two reasons. First of all, because it is not understandable that neither Hipparchos, nor Ptolemy nor many Greeks before them engaged in the "problem of restitution", though considerably closer in time to these events, knew about these eclipses. Perhaps, they have not been found in their manuscripts (Meton, Eudoks, Kalipa, etc)? There is only Simplicius of Kilikia (V cent. A.D.), a well known commentator of Aristotel's works, who heard, according to his own words, that Kalisten, Aristotel's nephew, following an order of Alexander the Great, after the conquest of Babylon had sent to Greece a big collection of Babylonian observations. However, such a collection never reached Greece.

On the other hand, one may not overlook the fact that many distinguished assyriologists (e. g. Rawlinson, Thompson, Strassmaier, Epping, Oppert, Kugler) by studying a large number of texts, just from the British-Museum tablets, have irrefutably established that they often are but scant communications about the observed, or "predictions" of, imminent celestial phenomena including the solar and lunar eclipses. Besides, it has been proved that such predictions, their "ephemerides", the Chaldeans could prepare up to a few years in advance as early as during the Persian domination (VI - IV cent. B. C.; Kambiz, Darius, Artaxerks) and later (IV - I cent. B. C.; Seleukids, Romans), even up to a few decades in advance (the Tables: Naburi anu, Kidinus').

The decoded texts on the tablets found in the ruins of other cities too, in the region of Mesopotamia, such as Uruk, Sipar, Borsipa, Nipur, etc, have also shown that the Babylonian priests-astrologers compiled among others "review" - lists about past and future eclipses ("Eclipses Indices", Pannekoek, 1961; Russian translation 1966).

In order to enable a clear distinguishing between the predicted events and the observed ones corresponding symbols were applied, though not always consistently; sometimes, probably due to mistake of the "scribe" or of someone else who rewrote the text of a tablet later on. *Kugler*, for instance, has established by comparing the records on about hundred tablets that in the particular case of eclipses the predicted ones differ from those really observed by the presence of the symbol "AN MI" in front of, instead of behind, the corresponding ideogram for the Sun (Sin), respectively of the Moon (Samas). Based on this finding the solar and lunar eclipses, as well as all other data contained on a tablet (CBS 11901) claimed by Weidener (Pensilvania University) to originate from the time of Kassits (X cent. B. C.), have been included by *Kugler* in the predicted events of the 40th year of Artaxerx's reign (425 B. C.). By contrast, according to *Schoch* the tablet contains observational data and the lunar eclipse recorded there is the most important among the ancient ones, significantly exceeding the importance of any of the Almagest eclipses (Schaumberger, 1935).

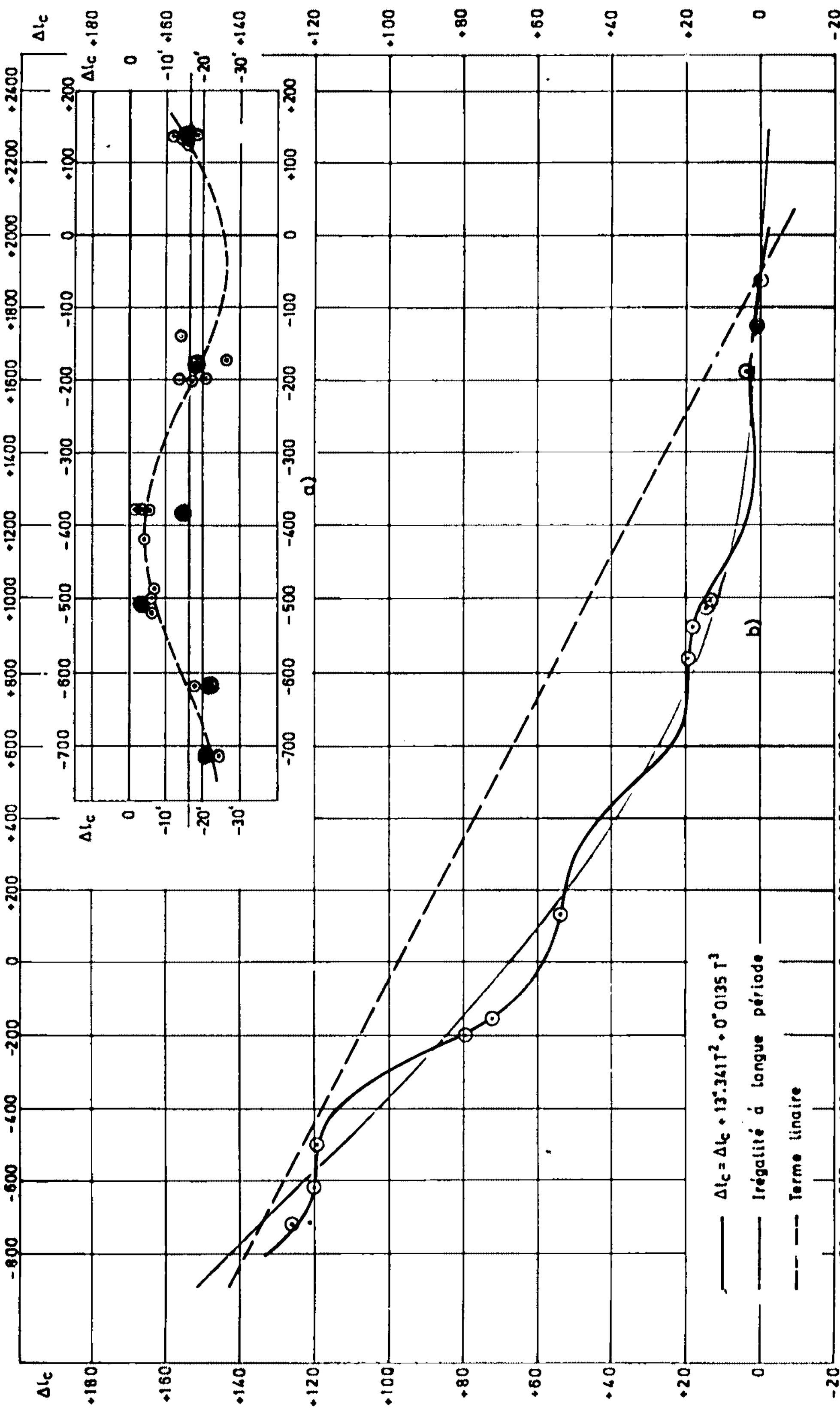

**Fig. 1ab.** *Residuals in the mean Lunar longitude $\Delta l_k$ from 720 B.C. to 1950 A.D.*

Table.1. BABYLONIAN-HELLENISTIC OBSERVATIONS OF LUNAR ECLIPSES

| N° (Newcomb) | Date | Observed UT time (Almagest) (MBP) | Phase | Calculated UT time (Almagest) (MBP) | O-C (MBP) | O-C (Newcomb) |
|---|---|---|---|---|---|---|
| | | h m | | h m | | |
| 1. | -720 Mar 19 | 18 41.0 | Middle | 18 05.1 | + 35.9 | + 8 |
| 2. | -719 Mar 8 | 21 16.8 | Middle | 20 28.9 | + 47.9 | + 63 |
| 3. | -719 Sep 1 | 16 05.3 | Beginning | 15 16.3 | + 49.0 | + 43 |
| 4. | -620 Apr 22 | 01 34.9 | Beginning | 00 56.5 | + 38.4 | + 44 |
| 5.* | -522 Jul 16 | 20 12.7 | Middle | 20 00.1 | + 12.6 | + 13 |
| 6.* | -501 Nov 19 | 20 40.0 | Middle | 20 27.4 | + 12.6 | - 5 |
| 7. | -490 Apr 25 | 20 30.5 | Middle | 20 18.5 | + 12.0 | + 10 |
| -.* | -424 Oct 09 | 15 24.6 | Beginning | 15 08.2 | + 16.4 | - |
| 8.* | -382 Dec 23 | 04 00.3 | Beginning | 03 54.9 | + 05.4 | - 17 |
| 9. | -381 Jun 18 | 16 29.2 | Beginning | 16 25.0 | + 04.2 | + 43 |
| 10. | -381 Dec 12 | 18 04.8 | Beginning | 17 57.0 | + 07.8 | + 59 |
| 11. | -200 Sep 22 | 18 28.7 | End | 17 53.9 | + 34.8 | + 30 |
| 12. | -199 Mar 19 | 21 29.6 | Beginning | 20 51.1 | + 38.5 | + 38 |
| 13. | -199 Sep 11 | 22 37.6 | Beginning | 22 13.7 | + 23.9 | + 25 |
| 14. | -173 Apr 30 | 22 48.6 | Beginning | 22 04.5 | + 44.1 | + 44 |
| 15. | -140 Jan 27 | 20 04.3 | Middle | 19 42.2 | + 22.1 | (+ 23) |
| 16.* | +125 Apr 05 | 18 26.4 | Middle | 17 58.1 | + 28.3 | - 10 |
| 17. | +133 May 06 | 21 09.1 | Middle | 20 37.9 | + 31.2 | + 30 |
| 18. | +134 Oct 20 | 20 53.0 | Middle | 20 36.1 | + 16.9 | + 13 |
| 19. | +136 Mar 06 | 02 00.5 | Middle | 01 30.4 | + 30.1 | + 48 |

5.* : Eclipse whose tablet was found (British Museum, London).
6.* : Probably wasn't observed from Babylon, but from Mari.
-.* : Eclipse decoded from tablet CBS 11901 (British Museum, London). Recorded neither in Almagest, nor in the Newcomb's table.
8.* : Eclipse probably observed at Palmyra (Tadmar); data had been brought from Chaldea (may be by Eudox).
16.*: Authors consider that it is the beginning of eclipse, but not its middle (by Newcomb).

Table.2. ARABIAN OBSERVATIONS OF SOLAR (S) & LUNAR (L) ECLIPSES

| N° (Newcomb) | Date | Observed UT time (Causin) (corr.MBP) | Phase | Calculated UT time (MBP) | O-C (MBP) | O-C (Newcomb) | |
|---|---|---|---|---|---|---|---|
| | | h m | | h m | | | |
| (S) 1.* | 829 Nov 29 | 04 07.8 | Beginning | 03 52.3 | + 15.5 | + 45.9 | B |
| (L) 7. | 927 Sep 14 | 01 04.0 | Beginning | 01 03.0 | + 01.0 | - 13.2 | B |
| (L) 9.* | 929 Jan 27 | 21 13.9 | Beginning | 21 04.2 | + 09.7 | - 58.8 | B |
| (S) 12.* | 978 Jun 08 | 12 04.4 | Beginning | 11 57.8 | + 06.8 | + 24.7 | C |
| | 978 Jun 08 | 14 42.2 | End | 14 38.3 | + 03.9 | + 03.5 | C |
| (L) 22.* | 990 Apr 12 | 20 12.6 | Beginning | 20 06.2 | + 06.4 | - 25.2 | C |

B - Bagdad; C - Cairo

1.* : h(S) = + 2.0° E  12.*: h(S) = + 60° W

9.* :h(Arct) = + 32° E  22.*: h(L) = + 42° E

Examples where the same text is interpreted in a different way by astrologers are not rare. According to Kramer, a well known American sumerologist, for the purpose of translating a text written in the cuneiform one should know sufficiently well the meaning of every ideogram which can be achieved only if one has previously penetrated deep enough into the contents of the text foreseen for translation (Kramer, 1959). When this is borne mind, it becomes clear why the choice of data read from the tablets requires to be very cautious. Inspections of records of the eclipses contained in the Almagest, however, exclude such confusions since they may be treated as really observed, $\alpha\delta\iota\zeta\alpha\kappa\tau\sigma\xi$ $\delta\sigma\kappa\nu\delta\alpha\iota\xi$ in Ptolemy's words.

In our attempt to examine what kind of solution can be obtained, if the secular term and the fluctuations in the mean lunar longitude are understood as an effect of existence of some unknown long-period inequalities in the lunar motion (idea occupying Newcomb as early as a century ago), we also decided to make a revision of the data derived by him from the ancient-eclipses observations (Newcomb, 1878).

The data presented in Table I are derived on the basis of our own analysis of the Greek texts given together with the French translation of Ptolemy's work (Halma, 1813). For the purpose of determining the theoretical instants of some eclipse phases we used Newcomb's data obtained on the basis of Hansen's Lunar Tables in the case of the eclipses for which in Newcomb's paper there are significant deviations compared to the neighbouring values we undertook original calculations.

It should be said that for eclipses No 2, 5, 6, 7 and 16 Newcomb states that in Ptolemy's texts it was not explicitly indicated to which phase the time data belonged so that he did not use them. It seems, however, that the true reason is a significant deviation (O - C) for these eclipses compared to others. As readily seen through a thorough analysis of Ptolemy's comments for every eclipse, including these too, Ptolemy regularly gives the time interval reckoned from the assumed initial epoch (first Nabonasar's year, noon on the first day of "Egyptian" month Tot), always reduced to the eclipse middle and to the midnight at Babylon, i.e. Alexandria, though applying the incorrect value for the longitude difference of these two places ($50^m$ instead of $58^m$!). Besides, he also gives the time interval between the mentioned eclipses which enables the verifying of his assumed times in hours of the equinoxial day. For instance, for the eclipse No 6, he sais that it took place 6 and 1/3 equinoxial hours elapsed from the beginning of the night 28/29 in Egyptian month Epiphi and that due to the fact that the midnight occured 6 and 1/2 and 1/4 equinoxial hours after the night had begun, the eclipse middle was at Babylon 2/5 (rounded to 25 minutes) equinoxial hours before the midnight and at Alexandria at 1 and 1/4 equinoxial hours before the midnight, i. e. 245 Egyptian years 327 days at 10 1/2 1/4 equinoxial hours elapsed from the beginning of Nabonassar's era (one Egyptian year = 365 equinoxial days).

For comparison in Table 1, in addition to our (O - C), we also present Newcomb's values. Besides, it also contains the corresponding revised data for a few Arab eclipses, rejected by Newcomb.

Converted into residuals in the mean lunar longitude (...) the eclipse data from the Almagest are also presented graphically (Fig. 1a). Their distribution seems to show an oscillatory behaviour with a period of about 700 years and an amplitude of approximately 10'. Newcomb's average values for individual groups are indicated by open circles. After the elimination of Hansen's secular term introduced empirically, which is by its modulus close to the value assumed by Stephenson and Morrison (27"), the behaviour of all deviations, including the Arabian and the modern ones as well, is presented in Fig. 1b.

If not only the increase in the observational accuracy over centuries is taken into account and if the dashed line in Fig. 1b connecting the three detached groups is accepted as presenting their most probable general behaviour, it is clearly seen that the amplitude of these "fluctuations" is damped within an interval corresponding to some unknown long-period inequality.

According to the first estimates the duration of this inequality exceeds several thousand years and at the maximum it attains a value of 2/3 of arc degree. More complete information concerning the results of our study will be published elsewhere.

Some of the eclipses given in Table 1 also require more thorough explanations:

(1) In the Greek text it stands that this eclipse began "more than an hour after the moonrise". It is not impossible that here the so-called "double hour" is meant and that for this reason Ptolemy assumed as the eclipse-middle instant 2 1/2 hours before midnight with the corresponding (O - C) +36 minutes. Since the moonrise at Babylon then was at 17 h 53 m Local Time, the eclipse beginning occured at 19h 55m Local Time (2 sz hours = 2h 2m) and the middle at 21h 45m LT (Oppolzer: total eclipse duration was 3h 45m). Hence (O - C): +42 m, close to the value given by Ptolemy and in accordance with the deviations for eclipses No 2 and 3. We note that the data bearing on the first three eclipses are taken from Theon's comments (Delambre, 1813), not from a copy of the Almagest (lost chapter), so that some error is possible.

(5) According to the found table Strm. Kamb. 400, the eclipse occured at 1 2/3 "beru" (3h 20m) after the night beginning, i. e. after the sunset. At Babylon the sunset took place at 19h 6m LT and the eclipse-beginning instant corresponds to 21h 50m considering that to an interval of 3h 20m of seasonal time corresponds 2h 44m of mean time (reduction factor 0.82). For the half-duration of this eclipse it was found by Oppolzer 76 m, resp. 82 m by Meeus (1983). If as the probable value used by Hipparchos the amount of 1 1/3h is assumed, then the middle of this partial eclipse will be at 23h 10 m mean time i. e. 50 m before midnight, or as a rounded value 1 hour season time before midnight, just as given by Hipparhos.

(6) If due to the dense penumbra the eclipse beginning had not been estimated earlier, the data concerning it could have been brought to Babylon from another zigurat. Bearing in mind the deviations for the eclipses from 522, 490 and especially 424 B.C., in this case also one should expect a positive value and the site of origin, west of Babylon, which at that time was the centre of satrapy in Darius' empire. There are several candidates among the cities because it was customary, following advice of astrologers, if the eclipse was not seen from the centre itself, to ask for the report from other sites (on a tablet from the British Museum the astrologer recommends: "Let the lord send heralds to Asur, Nipur, Uruk, Borsipa and all other cities in order to find out if the eclipse has not been seen there").

Most likely here we have the ancient city of Mari whose ruins have been discovered on the left bank of Euphrates, about 400 km northwest of Babylon.

(8) This eclipse does not appear in the Almagest and we have seen that the interpretations of assyrologers differ essentially among themselves. According to Tukidit, the eclipse was seen from Athens. Based on this one can conclude that it was, certainly, also observed at Babylon and as such registered on the mentioned tablet.

(9) As in the case of the eclipse (6) the data concerning this one probably originate from another place, not from Babylon. In Hipparchos text we find that "it was brought from that city", but here, doubtlessly, we have a terminological mistake because under the name of "Babylon" frequently the whole territory of Chaldea was understood. With such a hypothesis the place from which the eclipse was brought could be the city of Tadmar (Palmyra), ruined by the Arabs in VIII century A D. It cannot be excluded that it was brought, and perhaps observed, by Eudoxos who is known to have stayed in those regions and that he performed some astronomical observations there.

(17) The description of the phenomenon in the Greek text indicates that the time data correspond to the beginning of the eclipse, not to the middle as assumed by Newcomb. Oppolzer (1881) too thinks that the begining of the eclipse was involved.

The **f i n a l c o n c l u s i o n s**, taking into account all said above, should be:

- The doubts concerning the observed lunar eclipses recorded in the Almagest are groundless. This is confirmed by the original eclipse data from the year 522 B.C. (tablet Strm. Cambys. 400; British Museum) and by those for the eclipse from the year 424 B.C. (tablet CBS 11901; Museum of Pensylvania University). The former one proves that Hipparchos' text is quite correct. The latter one with its (O-C) negates Fotheringham's standpoint based just on the large difference of deviations for the eclipses from the years 382 B.C. and 381 B.C. with respect to all other eclipses;
- On the basis of these eclipses, together with the Arabian and modern ones, the deviations found in the mean lunar longitude can be considered as a natural consequence of the existence of certain long-period inequalities amortised and cyclically repeated over very long time intervals.
- However, the most important conclusion is that the constant decrease of the lunar longitude of about 8.8 x $10^{-3} arcsec/day$ during the last 26 centuries reduces its currently adopted value of mean motion to the value which was derived by Hipparchos and Ptolomy on the basis of the **same** lunar eclipses which are reported here!

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# РЕВИЗИЈА ПОДАТАКА ИЗ ПОСМАТРАНИХ ПОМРАЧЕЊА КОРИШЋЕНИХ У ИСТРАЖИВАЊИМА ЊУКОМБА

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*Стручни чланак*

Ослањајући се на грчке текстове о вавилонско-хеленским посматрањима Месечевих помрачења у Птолемејевом "Алмагесту" (Halma M., 1813) и анализом извесног броја записа о арапским посматрањима помрачења Сунца и Месеца, код којих је Њукомб установио знатна одступања у односу на усвојену теорију, извршено је проверавање резултата што их је он извео и користио при својим истраживањима.

Резултати ове ревизије и закључци до којих се долази на основу Њукомбове алтернативне претпоставке да су наведена одступања последица постојања једне или више непознатих дугопериодичних неједнакости у Месечевом кретању недвосмислено показују да ова посматрања ни у ком случају не треба одбацити.