Ptolemy's
ALMAGEST

Translated and Annotated by

G. J. Toomer

SPRINGER-VERLAG
NEW YORK BERLIN HEIDELBERG TOKYO
1984

6. {*Demonstration of the first, simple anomaly of the moon*}[27]

We shall now demonstrate
H301 the lunar anomaly in question, by means of the epicyclic hypothesis, for the reason mentioned. [For this purpose] we shall use, first, among the most ancient eclipses available to us, three [which we have selected] as being recorded in an unambiguous fashion, and, secondly, [we shall repeat the procedure] using, among contemporary eclipses, three which we ourselves have observed very accurately. In this way our results will be valid over as long a period as possible, and in particular it will be apparent that approximately the same [maximum] equation of anomaly results from both demonstrations, and that the increment in the mean motions [between the two sets of eclipses] agrees[28] with that computed from the above periods (as corrected by us).

[28] Reading σύμφωνος (with D, Ar) for σύμφωνος ἀεὶ ('always agrees') at H301,10.

For the purposes of demonstrating the first anomaly, considered separately, the epicyclic hypothesis which we mentioned can be described as follows. Imagine a circle in the sphere of the moon which is concentric to and lies in the same plane as the ecliptic. Inclined to this, at an angle corresponding to the amount of its [maximum] deviation in latitude, is another circle, which moves uniformly in advance (with respect to the centre of the ecliptic) with a speed equal to the difference between the motions in latitude and longitude. On this inclined circle we suppose the so-called 'epicycle' to be carried, with a uniform motion, towards the rear with respect to the heavens, corresponding to the motion in latitude. (This motion, obviously, will represent the [mean] motion in H302 longitude with respect to the ecliptic). On the epicycle itself [we suppose] the moon to move, in such a way that on the arc near the apogee its motion is in advance with respect to the heavens, at a speed corresponding to the period of return in anomaly. However, for the purposes of the present demonstration we shall suffer no ill consequences if we neglect the advance motion in latitude and the inclination of the moon's orbit, since such a small inclination has no noticeable effect on the position in longitude.[29]

First, the three ancient eclipses which are selected from those observed in Babylon.

The first is recorded as occurring in the first year of Mardokempad, Thoth [I] 29/30 in the Egyptian calendar [−720 Mar. 19/20]. The eclipse began, it says, well over an hour after moonrise, and was total.

Now since the sun was near the end of Pisces, and [therefore] the night was about 12 equinoctial hours long, the beginning of the eclipse occurred, clearly, 4½ equinoctial hours before midnight, and mid-eclipse (since it was total) 2½ hours before midnight.[30] Now we take as the standard meridian for all time determinations the meridian through Alexandria, which is about ⅚ of an equinoctial H303 hour in advance [i.e. to the west] of the meridian through Babylon.[31] So at Alexandria the middle of the eclipse in question was 3⅓ equinoctial hours before midnight, at which time the true position of the sun, according to the [tables] calculated above, was approximately ♓ 24½°.

The second eclipse is recorded as occurring in the second year of the same Mardokempad, Thoth [I] 18/19 in the Egyptian calendar [−719 Mar. 8/9]. The [maximum] obscuration, it says, was 3 digits[32] from the south exactly at midnight. So, since mid-eclipse was exactly at midnight at Babylon, it must

[29] I.e. for the purposes of computing the longitude the moon's orbit is treated as if it lay in the plane of the ecliptic. The maximum resulting error (for $\iota \approx 5°$) is about 6′ (cf. *HAMA* 83). Ptolemy himself (VI 7 p. 297) estimates it as 5′.

[30] A total eclipse of the moon is assumed to last 4 hours from start to finish. This agrees fairly well with the duration one derives from Ptolemy's own eclipse tables (VI 8) and with the actual maximum possible duration. The duration of the eclipse in question (Oppolzer no. 741) was in fact about $3\frac{3}{4}^h$.

[31] This time difference corresponds to a longitudinal difference of 12½°. The actual time difference is about 58½ minutes. In the *Geography* Ptolemy amended the difference, in the right direction but by far too much, to 1¼ hours (8.20.27), corresponding to the difference between the longitudes there assigned to Alexandria (60½°, 4.5.9) and Babylon (79°, 5.20.6).

[32] Modern calculations give a considerably smaller eclipse: Oppolzer (no. 743) 1.6 digits, P.V. Neugebauer 1.5 digits. However Ptolemy's own tables give about 2½ digits: see Appendix A, Example 11.

have been $\frac{5}{6}^h$ before midnight at Alexandria, at which time the true position of the sun was ♓ $13\frac{3}{4}°$.

The third eclipse is recorded as occurring in the (same) second year of Mardokempad, Phamenoth [VII] 15/16 in the Egyptian calendar [−719 Sept. 1/2]. The eclipse began, it says, after moonrise, and the [maximum] obscuration was more than half [the disk] from the north. So, since the sun was near the beginning of Virgo, the length of night at Babylon was about 11
H304 equinoctial hours, and half the night was $5\frac{1}{2}$ [equinoctial] hours. Therefore the beginning of the eclipse was about 5 equinoctial hours before midnight (since it began after moonrise), and mid-eclipse about $3\frac{1}{2}$ hours before midnight (for the total time for an eclipse of that size must have been about 3 hours).[33] So in Alexandria mid-eclipse occurred $4\frac{1}{3}$ equinoctial hours before midnight, at which time the true position of the sun was about ♍ $3\frac{1}{4}°$.

[33] At a lunar eclipse the moon is diametrically opposite the sun. Therefore moonrise coincided with sunset, which was $5\frac{1}{2}$ equinoctial hours before midnight. Ptolemy allows $\frac{1}{2}$-hour to account for 'after moonrise'. He estimates a duration of 3 hours for an eclipse of more than 6 digits (according to Oppolzer, no. 744, this eclipse had a magnitude of 6.4 digits and a duration of about $2;36^h$; P.V. Neugebauer calculates 6.1 digits and 2.4^h). Obviously this eclipse is hardly 'recorded in an unambiguous fashion' (p. 190).