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Observations and Predictions of Eclipse Times by Early Astronomers

by

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3.3.1 Babylonian Observations

The earliest ten lunar eclipses reported in the *Almagest* are all said to have been observed in Babylon. According to Ptolemy, Babylon is $\frac{5}{6}$ of an hour, or 12.5°, to the east of Alexandria. The true difference in longitude is about 14.5°. This discrepancy reflects one of the greatest problems faced by the ancient Greek astronomers: the determination of geographical longitudes. In his *Geography*, written about a decade after the *Almagest*, Ptolemy placed Babylon $1\frac{1}{4}$ hours ($18\frac{1}{2}°$) east of Alexandria. The probable reason for this discrepancy is that Ptolemy used a different value for the size of the Earth's circumference in the two works: the Eratosthenic value of 180,000 stades in the *Almagest* and Marinus of Tyre's value of 240,000 stades in the *Geography*. Thus an estimate of the east-west distance between Babylon and Alexandria derived from land measurements would convert into a different number of degrees on the two globes.[30]

There has been much debate over the years concerning the source for the Babylonian observations in the *Almagest*. As I have suggested above, Ptolemy probably obtained them from Hipparchus. But how did Hipparchus come to possess them? Did he travel to Babylon himself and persuade a Babylonian astronomer to translate the records for him, as has been suggested by Toomer (1988: 359)? Or was knowledge of Babylonian astronomy widespread among Greco-Roman astronomers? Certainly, Babylonian mathematical astronomy must have been known fairly widely. The Oxyrhynchus papyri show that astrologers both used and understood Babylonian ACT methods, and there is nothing to suggest that the Oxyrhynchus material would differ from that which would have been found in any other medium size city had the conditions for survival of papyri been as good. But the transmission of actual observations is a different matter. To be of any value in determining, say, some parameter of a lunar theory, not just any lunar observation will do. Eclipses, of course, are the most useful, but even then what one really needs are eclipses fulfilling certain conditions. Furthermore, these conditions are in part dependent upon the theory that one is developing. Thus, a Greek astronomer wanting to use Babylonian eclipse observations would probably have to obtain a long run of records, from which he could select certain ones at a later date.

The Babylonian records described by Ptolemy range in date from 721 BC to 382 BC. Even if these represent the earliest and latest reports available to him, Ptolemy must have had access to records covering a period about 350 years. Furthermore, this list of eclipses must have been fairly complete. It has generally been supposed that the original source for these records was the Babylonian Astronomical Diaries. However, there are good reasons for doubting that this was the direct source from which

[30]See Schnabel (1930: 218–219).

Hipparchus made his compilation. A typical Diary covers a period of six months, during which there will be one, or occasionally two, lunar eclipse possibilities (i.e., observations or predictions). In compiling a collection spanning 350 years, therefore, one would have to consult about 700 tablets. It seems unlikely that a Babylonian astronomer would read through all of these tablets, even if they were all preserved, and then explain them at the request of a visiting Greek. There is, however, another ready-made source which would have been of much greater use to Hipparchus: the large compilation of eclipse records, preserved in part on LBAT *1414, LBAT 1415 + 1416 + 1417, and LBAT *1419.[31]

As I have discussed in Section 2.5 above, when complete this large compilation probably comprised eight tablets and covered the period from 747 BC to 315 BC. The texts form a large matrix with each cell representing an eclipse possibility, successive cells in a row separated by either five or six months, and each column separated by one Saros from the preceding column. A direct translation of these texts, preserving their layout, would have solved many problems for Hipparchus. First of all, only eight texts would have to be consulted. Second, several chronographical questions would be answered. For instance, a more or less complete list of the length of each king's reign can be taken directly from the dates of the eclipses recorded in the compilation.[32] By the time they had reached the *Almagest*, the dates of the Babylonian observations had been converted from the Babylonian luni-solar calendar to the Egyptian calendar and the era Nabonassar. Hitherto, people have usually assumed that this would require abstracting the length of each Babylonian month from the Diaries,[33] but, as Alexander Jones recently pointed out to me, this would hardly be be practicable, particularly for the very early records. Fortunately, however, the structure of the large compilation allows one to avoid this problem. Assuming one knew the equivalent dates of the eclipses in the final column of the compilation (333–315 BC), which seems quite possible since Babylon was under Greek rule by that period and so there must surely have been documents detailing the concordance of the native calendar with the Greek calendar, one could obtain the dates of all the other entries in the compilation by using the fact that columns are separated by one Saros of about $6585\frac{1}{3}$ days. Although not exact, using the Saros in this way would allow the number of days between any two observations in the compilation to be calculated with scarcely any error.

It is probably significant that all of the Babylonian eclipse records described by Ptolemy come from the period covered by this large compilation. It may also be worthy of note that the only planetary observations which probably come from Babylon that Ptolemy uses are from the third century BC. As mentioned above, by this period Babylon was under Greek rule and we would expect that the Greeks would have an understanding of the native calendar in use at that time. Furthermore, the use of the Metonic cycle to determine intercalations in Babylon would have eased conversion of

[31] Toomer (1988: 359) and Walker (1997: 21) have both hinted that the Eclipse Texts could have been Hipparchus' source.

[32] In modern times, Parker & Dubberstein (1956) made extensive use of the Eclipse Texts in establishing Babylonian chronology.

[33] See, for example, Toomer (1988: 356), Depuydt (1995: 103), and Steele (1999b).

Babylonian dates to the Callippic calendar.

Let me now compare a record of an eclipse seen in Babylon as described by Ptolemy, with one from a cuneiform source.

> "The first eclipse we used is the one observed in Babylon in the thirty-first year of Darius I, Tybi 3/4 in the Egyptian calendar, at the middle of the sixth hour [of night]. It is reported that at this eclipse the moon was obscured 2 digits from the south..."
>
> [*Almagest*, iv, 9; trans. Toomer (1984: 206–207)]

> "Month VII, the 13th, in 17° on the east side, all was covered; 28° maximal phase. In 20° it cleared from east to west. Its eclipse was red. Behind the rump of Aries it was eclipsed. During onset, the north wind blew, during clearing, the west wind. At 55° before sunrise."
>
> [LBAT *1419, Obv. VI', 2'–8'; trans. Sachs & Hunger (1999)]

In addition to the different calendars, it should be noted that different units are used to quote the times of eclipse in the two sources. The cuneiform records invariably give the time of an eclipse in *bēru* and UŠ. However, Ptolemy generally gives the time of the Babylonian observations in seasonal hours. How did the times come to be converted into seasonal hours? It would not make sense to assume that Ptolemy himself did this, as his first step in analysing the records is to convert the seasonal hours back into equinoctial hours. This would suggest that the conversion was done either by the Babylonians themselves, or by Hipparchus when he compiled his list of eclipses.