CUNEIFORM MONOGRAPHS 18

MESOPOTAMIAN PLANETARY ASTRONOMY-ASTROLOGY

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STYX
PUBLICATIONS
GRONINGEN
2000

4.2.4.3 Predicting Eclipses

A number of studies of the eclipses predicted in the NA and NB Letters and Reports have been published. These include Schaumberger's *SSB* Erg.III 251f, van der Waerden's *BA* 115f, Parpola's *LAS* II on numbers 42 and 63 particularly, and Rochberg-Halton's *ABCD* 40f. See also Beaulieu & Britton (1994). The material has never been brought together before, however.

Eclipses Predicted, but which Failed to Occur

> "Concerning the watch about which the king, my lord, wrote to me, the Moon let the eclipse pass by, [it did not occ]ur" (x132: 6). See also x133: 6, x135: 7, x159: 4, x220: 10 (solar), x224: 8 (solar), x363: 7 (solar) & the -567 Diary: 17.

A "watch" for an eclipse implies that it was predicted. Lunar eclipses can occur every 5 or 6 months. That this was known by the late NA period is made clear from the Ninevite commentary text *ACh.* Sîn 3: 26 cited by Van der Waerden *BA* 116, Rochberg-Halton *ABCD* 41, and Schaumberger *SSB* Erg.III 251:

> "If the Moon is eclipsed not at its appointed time (*ina lā minātišu*) – six months have not elapsed, or alternatively, an eclipse occurs on the 12th or 13th day."

It is also suggested by x071, quoted below. At the most basic level lunar eclipses were predicted to occur at mid-month during a 2-month interval every 5–6 months. This form of prediction may even have occurred before the mid-8th century, though there is no reason to date the composition of *ACh.* Sîn 3: 26 to a period before c. 750 BC, and we have no other evidence for such predictions. In any case this type of prediction was not accurate. Indeed, *ACh.* Sîn 3: 26 is reminiscent of the ideal periods of the EAE Paradigm discussed in Ch.3.1.2. Much more accurate predictions of eclipses occurred in the late NA period, and it is these that are indicative of the new achievements of the PCP Paradigm.

Eclipses Predicted, but not Stated if they Occurred

"On the 14th Adad-šumu-uṣur enter[ed] Nineveh (saying) "Let him sit (on the throne) before the eclipse occurs"" (x377: 8). See also 8250: 1, 8251: r.6, 8320: 8, 8346: 4, 8382: 5f, x026: r.1, x114: 3f, x170 (solar), x216 (solar).

Eclipses Predicted not to Occur

"The Moon will be seen [with] the Sun in month VI on the 15th, it will let the eclipse pass by (Š of *etēqu*)" (8042: 1). See also 8046: 1, 8067: 1, 8087: r.1 8321: r.1, 8344: r.2.
"The 13th [day], the night of the 14th day is the [da]y of the watch, and there will be no eclipse. I guarantee it seven times, an eclipse will not take place. I am writing a definite word to the king" (8447: r.1). See also x046: 6.

There is no mention in these examples of why the Scholars were so sure that an eclipse would not take place. Some may have written to the king in months in which it was known eclipses could not occur. In the second quoted instance (and in x046), however, the Scholar was confident that an eclipse would not occur even though a "watch" for an eclipse was underway. Was this merely unfounded bravado? If not, it must have been based on a knowledge either that the eclipse would occur in the daylight and thus be invisible, or that the period between the last eclipse possibility and the one coming was now 6 months and not 5 (or vice versa). Alternatively, both pieces of astronomical knowledge may have been contained within the dictum that each eclipse possibility is preceded by the same 223 months earlier, but some 8 1/2 hours later in the day (see §4.1.2). This, of course, is the Saros interval, which could have been determined directly from the accurate records of eclipses.

Similarly, in the Eclipse Records from Babylonia (App.1 §32), eclipses are predicted to "pass by" (also *etēqu*, dib) in 731, 686, 684, 677, 668, and in 649 BC in the *Saros Canon* – *LBAT* 1414+. In *LBAT* 1414: 1f it is written:

1,50 mu-1-kam du-numun, bar *šá* dib *ina* 1 me nim
"110, Year 1 of Ukin-zēr (731 BC), (an eclipse) which passes by at 60 (UŠ) after Sunrise (literally, day risen)."

In other words a lunar eclipse was predicted to occur roughly 4 hours after Sunrise, and therefore in the middle of the day, when the Moon was below the horizon. The eclipse therefore "passed by". The same is noted in 684 BC (*LBAT* 1415: obv. II):

"Year 5 (of Sennacherib), month I, the 15th (an eclipse) which passes at [1]0 UŠ after Sunrise."

In these examples not only were the months and dates of these eclipses calculated, but the times of their occurrences – to the nearest 10 UŠ, or 40 minutes. Although the *Saros Canon* was written much later, and arranged eclipses into groups of 38 eclipse possibilities in 223 months, it would appear that *original* records were copied to that end. It is this that explains the developments over the decades seen in the details of what was recorded of the eclipses in the Canon, described above in §4.2.1. So, although it is conceivable that the eclipse predictions dating to 731, 686, 684, 677, 668, and 649 BC were actually *retrocalculations* undertaken by scribes in the 4th and later centuries BC, it is much more likely that they were *predictions* made and recorded shortly before each of those years, and that they were only later incorporated into the *Saros Canon*. How then were these predictions made?

Two possibilities exist, I believe. One is that the Saros interval was known. This would permit a prediction to be made of a forthcoming eclipse, provided the record of one 223 months earlier had been preserved. The forthcoming eclipse would be of the same type as the one 223 months earlier, but occur 8 1/2 hours, some 130 UŠ, later in the day. This might mean that the forthcoming eclipse would occur in the daytime, and so be invisible. These eclipses would be marked down as "passing by". Those predicted to occur *and* be visible would be watched for, and their *observed* details recorded.

The second possibility is that the predictions were made, but a few days in advance of the anticipated eclipse, using some simple scheme of lunar velocity. If on the 12th of the month, say, it was noticed that the Moon was in advance of its normal position *vis à vis* the Sun for that time of the year, then the Scholar might estimate that the Moon will reach opposition (the position for eclipse) during the day of the 13th and not during the night of the 14th, and so be invisible. Inconclusive evidence for both forms of prediction are present in the NA and NB Letters and Reports and the Eclipse Records.

Eclipses not Predicted, but which Occurred

> "If there is an eclipse in month III not (occurring) at its appointed date/hour/time (*ina lā minātišu*)" (8004: r.14).

This is an omen derived from the commentary text *ACh.* Sîn 3: 26, quoted above, but nevertheless may indicate that this eclipse did occur unexpectedly. It is noteworthy, however, that there are no other references, to my knowledge, of non-predicted eclipses taking place. The omen, no doubt, refers to the eclipse occurring after 5, rather than the *ideal* 6 months (see n354, above). This may have been an ideal period long known to the practitioners of the EAE Paradigm, but it may also have come about in the late NA period in the wake of the efforts at predicting celestial phenomena accurately for the first time. It was perhaps a result of the same feedback of the PCP Paradigm on the EAE Paradigm exemplified by those omens concerned with lunar latitude, discussed in §4.1.2.

Eclipses Predicted and Seen

> "Concerning the watch for the eclipse... on the 14th, during the morning watch, the clouds dispersed, and we were able to see. The eclipse took place" (x147). See also x351: 5f, 8279.

Many of the reported eclipses may also have been predicted.

The Days On Which Eclipses were Watched For

> "The night of the 13th... 14th... 15th... 16th (when) the Moon made an eclipse" (8279).
> "On the 28th, 29th, and 30th we kept watch for the eclipse of the Sun" (8363: 8).

These are indeed the possible days of the month on which eclipses may occur. There is no evidence that they were watched for on the 21st, for example, despite the existence of omen protases which described lunar eclipses occurring on this and other impossible days of the month (see Ch.3.1.1).

Period of Time During Which Eclipses Were Watched For

> "Concerning the watch of the Sun... we will keep watch twice, from the 28th of month VIII (and) from the 28th of month IX. Thus, we will keep the watch of the Sun for 2 months" (x045: r.1).
> "Concerning the lunar eclipse... it was observed... I shall keep watch for the solar eclipse" (x347: 5f).

These Letters show that solar eclipses were not always predicted to the month. Probably solar eclipses were watched for either side of a predicted lunar eclipse. See Parpola *LAS* II p51 and n385, above.

What Aspects of the Eclipses were Predicted?

> "If it should occ[ur], what is the word about it? – the 14th (signifies) Elam, month III (signifies) Amurru, and its decision is for Ur, and if it occurs, the quadrant[462] it afflicts and the wind blowing will be quoted as well" (x026: r.1).

This example indicates that a lunar eclipse was predicted by this Scholar to the *month* and *day*, but that he was unable to predict which quadrants would be covered. In 8250: 1f Nergal-eṭir gives a very confident prediction of an eclipse, indicating the month, day, the *watch*, and the *presence of the planets*:

> "In Adar (month XII) on the 14th day the Moon will make an eclipse... In the Moon's eclipse, Jupiter and Venus [will not? stand] there... If there is an eclipse in Adar in the evening watch... When the Moon has made the eclipse, let the king write and have dikes cut in Babylonia at night as a substitute for the king".

We cannot be sure that the eclipse occurred, though it seems likely. In x071: 6f we find:

> "Concerning the watch for the lunar eclipse... its watch will be [on the deci]ded [night]; [whether] its [wat]ch should be during Sunset [we have not been able to decide]. [Eclipses] cannot occur [dur]ing certain periods. [...] 4 months there was a watch in month VIII and now in month IX we will (again) keep watch."

This Letter is fragmentary, but enough remains to show that this lunar eclipse was predicted only to within an interval of 2 months, separated by a period of probably 4 months, during which time an eclipse was known never to occur. This 2-month interval was the time of the eclipse "watch". The prediction in this text apparently relied on no more than the fact that eclipses can occur every 5–6 months, or even on the ideal period of *ACh.* Sîn 3: 26. Importantly, the Letter also indicates that *sometimes* the watch during which an eclipse might take place was predictable, though not in this case (assuming the reconstruction is good). This is confirmed in x078: 1':

462 *Kaq-qu-ru*, for which see Parpola LASII p29 r7'.

"[Concerning the watch for the lunar eclipse]... its watch will be tonight, in the morning watch. The eclipse will occur during the morning watch,"

which indicates that once the month, and perhaps the date of an eclipse were established the watch in which it was thought to occur could then sometimes also be predicted. This is shown here because this Letter is a response to the king's enquiry about the watch, *once* the king had heard that an eclipse was anticipated. Predictions at this level of accuracy are comparable to those recorded in the Babylonian Eclipse Records discussed above, and the methods used there were probably the same as those used by the Scholars employed by the Ninevite court. The above example suggests that in this case, at least, methods other than those using the Saros interval were employed.

In *LAS* II p68 Parpola argues that the prediction of the watch was made only a few days in advance, perhaps from calculations derived from the Moon's visibility periods sometime before opposition. As proposed above, if the Moon were visible after Sunset for longer than expected on the 12th, say, it meant that that the Moon had travelled further in its path than usual. Opposition, and any eclipse, would therefore occur earlier than expected, enabling the Scholars to assert that the eclipse would take place in the evening watch, say. In x240: 23f, on the 13th, or thereabouts, an eclipse is predicted for the night of the 15th:

"I shall now look up, collect and copy numerous – 20 to 30 – canonical and extraneous tablets, (but) perform (the prayers) tomorrow evening and on the night of the 15th... I am also worried about the impending observation of the Moon; let this be [my] advice: If it is suitable, let us put somebody on the throne. (When) the night [of the 15th day] comes, he will be afflicted [by it (the eclipse)], but he will *sa*[*ve your life*]!"[463]

Some Scholars did, then, estimate the watch and the day of forthcoming eclipses a few days in advance of lunar opposition, probably relying of a simple notion of lunar velocity, as described. Some predictions, however, were also made long in advance:

How Long in Advance were Eclipses Predicted?

In 8388 Rašil writes that an eclipse will occur on the 14th and boasts:

"(Already) when Venus became visible, I said to the king my lord, "An eclipse will take place.""

This was, presumably, sometime earlier, though as I explain in App.2 (year 667) we cannot be sure how much earlier this was.

In x224 (dating to 667/VII/30) and x363 (669/IV/1) eclipses were predicted which did not occur. In both instances a solar eclipse was predicted 2 weeks after the lunar eclipses of 667/VII/14 and 669/III/14 respectively, demonstrating that solar eclipses were watched for either side of lunar eclipses, as suggested above. In x351 a predicted eclipse (that it was predicted is shown by the fact that in line 5f a substitute is described as being already prepared before the date of the eclipse) took place on 671/X/15. It was preceded by an eclipse in 671/IV/14, 6 months earlier. Perhaps this was the basis of the prediction. In x358: r.7 it is written:

463 See also Parpola, *LAS* II p176f.

> "They (the more expert Scholars?) say "(Concerning) the watch for the Moon, he (the Moon) will make (the eclipse) pass by in the intercalary month VI_2; it will take place in month VII,"

which shows that the predictions were made at least some months in advance. See my discussion of the redating of this letter to 670 BC in App.2. In 8502: r.7 we find:

> "All the signs which have come concern the land of Akkad... An eclipse of the Moon and Sun in month III will take place. These signs are of bad fortune for Akkad... and now, in this month IX, an eclipse will take place... and Jupiter will stand in its eclipse."

8502 is datable to 679 BC, and shows that *some* eclipses were predicted at least 6 months in advance, and with enough detail to be sure that at the time of eclipse Jupiter would be visible. While estimating Jupiter's approximate location 6 months hence is trivial, since it moves so slowly, to be sure that it will then be above the horizon at the time of an eclipse requires knowledge *now* of the time of day or night at which the phenomenon occurs. Only the Saros interval could provide such knowledge.

8502 provides the clearest piece of evidence that the Scholars used the Saros interval. It could, of course, be argued that its Babylonian author merely guessed that Jupiter would be above the horizon in the forthcoming eclipse. One further tiny piece of evidence from the Babylonian Eclipse Records, however, suggests to me that the Saros interval of exactly 223 months, incorporating 6585 days and about 81/2 hours was known as early as the mid-8th century BC. This is the writing of the numbers 1,40 and 1,50 at the very beginning of *LBAT* 1413: Ii and *LBAT* 1414: Ii, respectively – the last quoted above. These numbers are obscure, but appear to pertain to the year in question and to be in UŠ, since all other large numbers in the Eclipse Records are in this unit. I tentatively suggest that these numbers indicate the amount of time by which 223 months were thought to exceed 6585 days. In other words they indicated to the compiler of the records how much later in the day an eclipse similar to one 223 months earlier would occur. 1,40 and 1,50 are a little smaller than the mean value of the function Ø, which models how much longer than 6585 days 223 months are (see §4.1.2), but only by some 15 to 20%. Indeed 1,50 UŠ (=110) is close to the minimum value for function Ø. As noted above, in *LBAT* 1414: Ii a prediction was made as to when in the day, April 9th 731 BC, an invisible eclipse was to occur. The figure of 1,50, and a record of an eclipse 223 months earlier was used to make this prediction, I suggest. The eclipse was predicted to take place at 60 UŠ after Sunrise, in which case the text implies that 223 months earlier an eclipse occurred some 50 UŠ *before* Sunrise. Modern records show that on the 28th March, 749 BC an eclipse did indeed occur between c.4 am and 6 am local time.[464] The eclipse set as it ended, so it began about 2 hours or 30 UŠ before Sunrise. Depending on the precise definition of the length of Sunrise, these figures indicate that it was quite possible that the invisible eclipse of 731 BC was predicted using the Saros interval in which the amount by which 223 months exceeded 6585 days was then considered to be 150 UŠ.

The evidence for the use of the Saros interval before 612 BC is not conclusive. It must be asked why it was not used more generally by the Scholars. Why were watches made for eclipses that never occurred? Careful use of the Saros interval would have shown whether or not an eclipse would be visible. I argue, though, that the accurate prediction of celestial phenomena was an art in its infancy in the late NA period. Undoubtedly, not all the Scholars

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464 Steele & Stephenson (1997/8) 200.

were equally competent at it. It is noteworthy that the author of 8502, the text which provides perhaps the best evidence of the use of the Saros, was a very senior Babylonian Scholar. Although, his name is lost, he states to the king in r.12f:

> "Let the king do this, (and) what ever Bēl-ušezib will write to the king his lord, and I will guarantee it the king, my lord."

Bēl-ušezib was perhaps the most senior Babylonian Scholar employed by Esarhaddon and his father Sennacherib. A large number of his Letters and one Report have been preserved. The author of 8502 was either senior to Bēl-ušezib, or felt himself to be his equal. Perhaps he was amongst the few who knew of the predictive power of the Saros. In Ch.5.1.2 I will discuss the fact that many aspects of the PCP Paradigm were kept secret. If I am correct about the significance of the number 1,50 in *LBAT* 1414: Ii and of 1,40 in *LBAT* 1413: Ii, then since the latter possibly dates from as early 747 BC, this would mean that accurate records of eclipses were made at least some years before 750 BC. At least 223 months of records would be needed to determine a rough value for the amount by which the interval between eclipses separated by that time interval exceeds 6585 days. Without such records, however, this is merely speculation.

To sum up, the Scholars were interested in predicting eclipses. Many used the simplest possible period for eclipse prediction, of 5 or 6 months, but some, I argue, knew and used the longer 223-month period we call the Saros.[465] The 5/6-month period provided the Scholars with the knowledge that a lunar eclipse might happen in the middle of a particular month. Sometimes the prediction of the precise day may have been no more than a statement that eclipses *usually* happened on the 14th. Knowing the month in which a lunar eclipse might occur also ensured that the Scholars looked for solar eclipses at the beginning and end of that month. Predictions of eclipses to days other than the 14th and to watches, predictions of invisible eclipses, and the prediction of the visibilities of planets during an eclipse, were probably often done only a few days in advance of each event, but some Scholars, at least, were able to undertake them long in advance.

This concludes our summary of the current understanding of the extent of the Scholars' ability to predict planetary phenomena in the period c. 750–612 BC. Most important is the evidence that they *intended* to predict them, and that they felt confident enough to write to the

[465] The Saros period may have been built up from shorter periods after which eclipses recur – see Britton (1989) 5–9. Parpola *LAS* II p51 argues that "the scholars of this period certainly had recognised the 47-month period and probably the 18-year Saros." He points to van der Waerden *BA* 118, but van der Waerden in fact argues that the "eclipse not at its appointed time" in 8004: r.14 (quoted above) can only be accounted for on the basis that the Scholars were aware that *total* eclipses were normally followed by eclipses 6 months later, where *partial* eclipses were usually followed by eclipses 5 months later. This is true, but the *ina lā minātišu* omen in 8004 most likely simply indicated that it was remarkable that the eclipse occurred after 5 months and not 6 because of the ideal nature of 6, irrespective of the type of eclipse seen 5 months earlier. The 47-month eclipse period is thus unattested, and its merely being shorter than the 223-month one hardly constitutes grounds for believing it was discovered or used first. Speculating how the Saros period was determined is pointless in the absence of more evidence. We know that it was in use by the mid-5th century BC as part of function Ø, and probably used to determine the lunar six by the early 6th century BC, as the -567 Diary indicates. The determination in the late NA period of month lengths, eclipse times months in advance, and the presence of parameters comparable in magnitude to those in function Ø in texts whose purpose was also eclipse prediction, suggests that if one long eclipse period *was* known then it was undoubtedly the Saros.

king and tell him of their calculations. Their reputations were at stake when they did this. The Scholars were interested and capable of regulating the luni-solar year, and they had available to them both the accurate records of eclipses and planetary phenomena, and the characteristic periods after which they recurred. Their Letters and Reports show that some of them made predictions of planetary behaviour, using, at the very least, a characteristic period for Venus and some model of lunar velocity, and probably the Saros for eclipses. They also predicted lunar phenomena with an accuracy that remains difficult to evaluate as yet, but which may also have depended on the Saros and/or models of lunar velocity.

At the end of §4.1.2, I argued that it was necessary for the thesis of this book, only that the core hypothesis of the PCP Paradigm was being implemented in the late NA period. The core hypothesis was that the accurate record of ominous phenomena would enable the same phenomena to be predicted through the use of characteristic periods and parameters. There can be no doubt, now, that this premise was embraced by those authors of the Letters, Reports, Diaries, Eclipse and Planetary Records and related material. This hypothesis was their *revolutionary thought*. They were interested in predicting phenomena in advance, and they did so. Some of their methods can be reconstructed, and these were directly ancestral to the NMAATs and MAATs of later centuries. Mesopotamia was famous in the ancient world for its predictive astronomy (see nn5 & 9, above) and for its celestial divination, in other words for the PCP Paradigm. The Paradigm came to have an enormous impact on subsequent Western astronomy and astrology. The reasons why this facility to predict celestial phenomena came about in the late NA period, and the significance of this to a study of the history and philosophy of science will be the subjects of the next and concluding chapter.