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ASTRONOMICAL DIARIES AND RELATED TEXTS FROM BABYLONIA

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Lunar and Planetary Texts

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Errata

On p. 392, footnote 4: Add: A similar explanation was proposed by D. Brown, Mesopotamian Planetary Astronomy-Astrology (Groningen 2000) p. 205f.

The figures 1 and 2 mentioned in the first paragraph of p. 392 were erroneously left out in printing. Very similar ones can be found in the article listed on p. 391 footnote 1.

APPENDIX: THE ECLIPSE TEXTS

by John M. Steele

The Eclipse Texts published in this volume fall into five main categories: (i) straightforward lists of consecutive eclipse observations and predictions, (ii) lists of consecutive eclipse observations and predictions arranged in 18-year cycles, (iii) texts containing consecutive eclipse observations and predictions together with other material, (iv) reports of individual eclipse observations, and (v) theoretical texts. Four other theoretical texts listing the months of eclipse possibilities are known: BM 36910 + 36998 + 37036, BM 37044, BM 34597 (the 'Saros Canon'), and BM 36754 (the 'Solar Saros'). These have been published as texts A, B, C, and D respectively by A. Aaboe, J. P. Britton, J. A. Henderson, O. Neugebauer, and A. J. Sachs, *Saros Cycle Dates and Related Babylonian Astronomical Texts*, Transactions of the American Philosophical Society 81/6 (Philadelphia, 1991), and I will refer to them by these letters. Listed below are the various texts which fall into each category. It is unclear whether texts 7, 16, 17, and 32 fall into categories (i) or (ii), but it seems most likely that at least no. 16 is arranged in 18-year cycles.

Category	Texts
i	1, 6, 8, 15, 33
ii	2, 3, 4, 9, 10, 11
i or ii	7, 16, 17, 32
iii	5, 12, 13, 23
iv	14, 18, 19, 20, 21, 22, 24, 25, 26, 27, 28, 29, 30, 31, 34
v	35, A, B, C, D

The five texts in category (i) all contain details of consecutive lunar eclipse possibilities. No straightforward lists of solar eclipse records are extant; however, this is probably due solely to the accidents of preservation. The preserved category (i) texts do not appear to be part of a single series since there is considerable variation in the layout and content between the various texts. For example, texts 1 and 15 appear to be written in only one column whereas texts 6, 8, and 33 are divided into at least two columns on each side. Horizontal rulings are sometimes used to separate successive eclipses (text 15) or groups of eclipses for each year (text 6). There is also considerable variation in the amount of details reported for each eclipse in the different texts. Texts 1 and 6 give only a brief account of each observed eclipse and only the date of predicted eclipses, whereas the other texts tend to give many more details of the observations and an expected time for the predicted eclipses.

The earliest predictions contained in these texts may simply have been made using the basic rule that eclipse possibilities generally occur every six months, but occasionally after only five months. However, cycles were also used to predict eclipses - most importantly, the Saros of 223 synodic months or slightly more than 18 years. Within each Saros there are 38 eclipse possibilities of which 33 take place six months after the preceding possibility and 5 take place five months after the preceding possibility. By distributing these five month intervals as evenly as possible we obtain a scheme whereby each Saros is divided into five groups

containing respectively eight, seven, eight, seven, and eight eclipse possibilities (this arrangement is conveniently written 8-7-8-7-8). The first eclipse in each group is five months after the preceding eclipse possibility and the remaining eclipses are at six month intervals. The scheme then repeats after each Saros period of 18 years.[1] The eclipse predictions contained in text 6 follow just such a scheme and, more importantly, tell us where the scheme began (in other words which eclipse possibility was considered to be the first eclipse in the first group of the 8-7-8-7-8 arrangement). This was the eclipse of -602 May 3 or an eclipse a multiple of 223 months earlier. It should be noted that the 8-7-8-7-8 arrangement could equally well be written 7-8-7-8-8, 8-8-7-8-7, etc. This would simply mean that we have to change our definition of the beginning of the scheme. Thus, the layout of text 6 could also, for example, be described as following an 8-8-7-8-7 distribution starting with the eclipse possibility on -606 July 15, or a multiple of 223 months earlier. These schemes are identical. Text 6 was probably compiled shortly after -575, which indicates that the scheme for distributing eclipse possibilities within the Saros must have been developed by at least this date.

The texts in category (ii) are all arranged in columns such that each entry in a column is separated from the entry in the preceding column by one Saros of 18 years. Texts 2, 3, and 4 all appear to be part of the same series containing lunar eclipses and were probably written by the same scribe.[2] The texts turn sideways and when complete would have contained 12 columns on each of the obverse and reverse, making 24 columns in all. These three tablets have the appearance of a matrix with rows and columns separated by horizontal and vertical rulings. Each cell contains one eclipse possibility. To illustrate the structure of these texts, I give below the layout of part of the reverse of text 3. In the texts, each cell of the matrix contains a detailed account if an eclipse was observed or an expected time if it was predicted.

Darius II, 8, XII, 13	Artaxerxes II, 7, XII_2, 14	Artaxerxes II, 26, I, 12
(-414 March 26)	(-396 April 5)	(-378 April 17)
Darius II, 9, VI, 13	Artaxerxes II, 8, VI, 14	Artaxerxes II, 26, VII, 13
(-414 September 19)	(-396 September 30)	(-378 October 11)
Darius II, 9, XII, 14	Artaxerxes II, 8, XII, 14	Artaxerxes II, 26, XII_2, 15
(-413 March 16)	(-395 March 26)	(-377 April 6)

It seems that these three texts are part of a large compilation that contained records of all of the eclipse possibilities for 24 Saros cycles, stretching over a period of 432 years and containing 912 entries. From the preserved fragments of this compilation it must have started with an eclipse possibility between - 747 March 18 and - 739 March 20, and have ended with the eclipse possibility 5347 synodic months later, between - 315 December 2 and - 307 July 9. Given that the tablet thought to contain the earliest lunar eclipse records (text 1) apparently begins in - 746 February 6, it seems quite possible that the large compilation also began with this eclipse possibility, especially since this eclipse was at a five month interval.

Running throughout this large compilation is the expected distribution of lunar eclipse possibilities arranged in the 8-7-8-7-8 pattern. So far as it is preserved the arrangement is exactly the same as that given on text 6 (see above). This fact suggests that the scheme was used throughout the period covered by the large compilation (although it is possible that some of the earliest predictions could have been made by projecting the scheme backwards when the text was compiled). In support of this I may note that all of the eclipse observations and

[1] See J. M. Steele, 'Eclipse Prediction in Mesopotamia,' *Archive for the History of Exact Science* 54 (2000), 421-454.

[2] On these texts, see already C. B. F. Walker, 'Achaemenid Chronology and the Babylonian Sources,' in J. Curtis (ed.), *Mesopotamia and Iran in the Persian Period: Conquest and Imperialism 539–331 BC* (London, 1997), 17-25, on which the following discussion is in part based.

predictions recorded in the other eclipse texts and the diaries of this period are also in complete agreement with the arrangement of eclipse possibilities found on text 6. It is therefore possible to reconstruct the complete layout of the compilation, as I have done in figures 1 and 2. Figure 1 shows the dates of the eclipse possibilities on the obverse of the tablets in the large compilation, based upon the assumption that it began with the eclipse on - 746 February 6.[3] Reading down the columns the dates are separated by six months, except where I have left a blank row in which case there is an interval of only five months. In the texts themselves, the five month intervals are noted by the words 5 ITU after the date of the eclipse possibility. For reference, dates of eclipses which were theoretically visible according to modern computations are given in bold in the figure. I have also outlined the parts of the compilation which are preserved on texts 2, 3, and 4. Figure 2, which has exactly the same layout as figure 1, shows the reverse of the tablets in the compilation. It is not certain from the preserved texts how many tablets would have been needed to contain the original compilation, but if C. B. F. Walker is correct in suggesting that each tablet contained records of about 5 eclipses in each column, then eight tablets would be needed to cover the complete Saros.

It should be noted that there are four accounts of eclipse observations in texts 2, 3, and 4 which, by modern computations, could not have been made. It seems most likely that these eclipses were wrongly filed by the compiler of the large compilation. Given that it would have contained over 900 entries this is perhaps not surprising. Generally, however, the accounts turn out to be fairly accurate when compared with modern computations.

Of the remaining tablets which form the large compilation, only for text 2 is part of the left edge preserved. We find in Obv. 1, 1' the number 1;50 before the usual entry for the date of the eclipse. Unfortunately, this is the only entry preserved next to the left edge, and so we cannot be sure if similar numbers were written next to the other eclipses in the first column of the large compilation. However, since no similar numbers are found in the entries in the other preserved columns, it seems possible that this number was intended to apply to every eclipse in that row of the compilation. Similar numbers (1;40 and 2;10) are found on the left edge of text 1. If we read these numbers as time intervals in UŠ, in each case they give a fairly good approximation to the excess length of the Saros over a whole number of days. The length of the Saros can vary between about 95 and 135 UŠ, but is almost constant for eclipses within the same Saros series (ie. along the same row of the large compilation). This may explain why the number was apparently only written before the eclipses in the first column of the compilation. Most probably these numbers were used when making predictions of the times of the eclipses.[4]

Another text in category (ii) dealing with lunar eclipses is text 9. This tablet turns normally but the columns continue from the obverse over onto the reverse. Eclipse possibilities are sometimes separated by horizontal rulings, but placement of these rulings does not appear to follow any pattern. As noted above, this text follows the same arrangement of eclipse possibilities within the Saros as text 6. Finally, text 10 also contains lunar eclipses arranged in 18-year cycles. Only one side of this tablet is preserved, but it seems that columns were separated by vertical rulings, and successive eclipse possibilities within a column by horizontal rulings. The very badly damaged reports in column I are for the same eclipses as those described by Ptolemy (from Babylonian observations) in *Almagest*, iv, 11.

Four of the category (v) theoretical texts also set out lunar eclipse possibilities in Saros cycles. Text 35 contains the years and months of lunar eclipse possibilities from parts of the period -663 to -573. The dates are sometimes followed by a number and once by the term BE. The significance of this number is not known but it is possible it may be related to the magnitude of the eclipse calculated by some simple scheme similar to that found on an

[3] To save space, dates in the table are given in the Julian calendar.

[4] This will be discussed further elsewhere.

Achaemenid list of solar eclipse possibilities that has become known as text S.[5] Whatever the meaning of these numbers, the arrangement of the eclipse possibilities in text 35 follows the same pattern as that found on text 6 and in the large compilation. Texts A, B, and C contain simply a list of the years and months of eclipse possibilities, together with details of intercalary months, and the remark 5 ITU noting the occurrence of a five-month interval in the prediction scheme. All three texts follow the same arrangement of five-month intervals within the Saros, which I shall call the Saros Canon scheme, and when complete would probably have covered the period from - 526 to - 256. Interestingly, this Saros Canon scheme, whilst still having the expected 8-7-8-7-8 distribution of eclipse possibilities,[6] differs from that implied by text 6 and the large compilation as it begins with a different eclipse possibility.[7] Thus in the Saros Canon scheme the five month intervals appear before different eclipse possibilities than in the earlier scheme from text 6. Clearly, therefore, the Saros Canon cannot be seen as a guide to the eclipse records in the diaries and earlier texts as has previously been suggested, but rather as an alternative scheme for predicting eclipses which was not used in making the predictions for the diaries.[8]

The final tablet in category (ii), text 11, is the only known example of a list of solar eclipse observations and predictions arranged in 18-year cycles.[9] The tablet turns normally, but the four columns on the obverse continue onto the reverse. These columns are separated by vertical rulings, and horizontal rulings separate successive eclipse possibilities. According to Walker, it is possible that when complete each column of the tablet may have contained all 38 eclipse possibilities within a Saros. Unfortunately, only a little is preserved, but what there is follows the usual pattern of 8-7-8-7-8 eclipse possibilities within a Saros. The theoretical text D, known as the 'Solar Saros,' contains the years and months of solar eclipse possibilities arranged in 18-year cycles. The five month intervals in this text do not follow the expected 8-7-8-7-8 pattern; however, this may be due to a scribal error and a correction has been proposed by A. Aaboe et al. to obtain the expected distribution.[10] So far as it is preserved, text 11 is in agreement with this corrected layout.

The texts in category (iii) contain a wide variety of material including eclipse reports. Text 5 records astronomical observations and historical events in the reign of Nabopolassar. The historical accounts parallel those in a chronicle describing the tenth to the eighteenth year of his reign (BM 21901, see A. K. Grayson, *Assyrian and Babylonian Chronicles*, Texts from Cuneiform Sources 5 (New York, 1975), 90- 96).

Texts 12 and 13 are apparently from the same tablet but do not join. When complete the text would have contained a combination of lunar six data and lunar and solar eclipse records dating from parts of the reigns of Darius and Alexander. On the obverse, lunar six data are recorded month by month in a number of columns. Each month is separated by a horizontal ruling. The reverse contains eclipse records apparently arranged in columns which alternate between lunar and solar eclipses. Eclipse possibilities are separated by horizontal rulings within each column. Text 23 also contains a combination of lunar six data and eclipse

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[5] Published by A. Aaboe and A. Sachs, 'Two Lunar Texts of the Achaemenid Period from Babylon,' *Centaurus* 14 (1969), 1-22. On the magnitude scheme, see O. Neugebauer, *HAMA*, 526-527 and J. P. Britton, 'An Early Function for Eclipse Magnitudes in Babylonian Astronomy,' *Centaurus* 32 (1989), 1-52.[6] In fact the text is set out in such a way that the eclipse possibilities follow an 8-8-7-8-7 distribution, but, as mentioned above, this is analogous to the 8-7-8-7-8 distribution.

[7] The little that is preserved of text B actually agrees with both the Saros Canon scheme and the earlier scheme.

[8] For futher details, see Steele, op. cit.

[9] On this text, see already Walker, op. cit.

[10] Aaboe et al., op. cit., 28-29.

reports. In this text, however, the lunar six data is mixed together with the lunar and solar eclipse possibilities in chronological order. The text originally contained at least four columns on each of the obverse and the reverse. These columns are separated by vertical rulings but do not continue from the obverse to the reverse.

With the exception of text 34, all of the texts in category (iv) contain an account of a single observed eclipse. In most cases they are written on small square tablets and often appear to be library texts. The eclipses described in two texts (22 and 24) are also recorded in (badly damaged) diaries and, so far as it can be judged, it seems that the accounts run more or less parallel. This suggests that the individual reports were simply drawn directly from the diaries for those years. One may also note the similarity between these texts and some of the 'short diaries.' Diary no. - 238 (BM 55511), for example, contains only a report of the lunar eclipse of - 238 April 28 and other observations made on that night. Perhaps some of these individual reports were also preliminary descriptions of eclipse observations that would then have been used in compiling the longer 6-month diaries.

Text 34 appears to contain a report of an observation of a lunar eclipse which is unfortunately badly damaged and has not yet proved datable. Unusually, this report is written at right angles to the other lines of the tablet. In addition to this apparent eclipse observation, Text 34 contains three columns that continue from obverse to reverse and give regnal years (each separated from the previous one by 18 years), the royal name, and the number 18 which is well known as the Babylonian terminology for the Saros period. Thus it has become known as the 'Saros Tablet.'[11] The preserved text begins with year 38 of Nebuchadnezzar II and covers the period down to year 213 of the Seleucid Era. However, as noted by Kugler, it is conceivable that the text originally began with the accession year of Nabonassar in - 746. As the text makes explicit reference to the Saros period, it seems most likely that it is somehow connected with eclipses, particularly in light of the apparent observation of a lunar eclipse recorded on the same tablet. In all probability, the years refer to eclipse possibilities separated by one Saros. Assuming these are lunar eclipses, then if the text did originally extend back to - 746, which is not yet proven, it would begin with the eclipse observed in month XII of the year of Nabonassar's accession. This is the same eclipse as is probably reported in line 2 of text 1, and is the first entry in our reconstruction of the large compilation (texts 2, 3, and 4). Moving on by one Saros for each line in the Saros Tablet, the year of the eclipse possibility would increase by 18 and the month would gradually progress from XII to I through to XII again. Only when the month of the eclipse possibility changes from XII or XII_2 to I would the year increase by 19 instead of 18. This would happen in - 656 (or perhaps in - 674 as our knowledge of the calendar is uncertain at this early period). Assuming that the text took into account the correction to the way eclipse possibilities were distributed within a Saros period which took place in about - 250,[12] then it could continue down to year 213 of the Seleucid Era by simply adding 18 years onto the previous year number. However, the eclipse possibility in this year was in month XII_2 and moving on by one Saros we would get an eclipse possibility in month I of year 232 of the Seleucid Era, nineteen years after the preceding year number. It therefore seems significant that the text ends at this point. Perhaps the text did not begin with the eclipse in month XII of - 746, but rather in month I of - 656 or - 674. The text would therefore relate to eclipse possibilities which gradually moved throughout the year from month I to month XII_2, always at an interval of 18 years from the preceding line.

[11] For previous discussions, see J. N. Strassmaier, *ZA* 7 (1892), 198-201 and *ZA* 8 (1893), 106-107, and F. X. Kugler, *SSB II*, 362-366.

[12] This correction has the effect of increasing the date of eclipse possibilities in this Saros series by one month. Other corrections to the Saros were also introduced but would not have affected these particular eclipses. For details, see Steele, op cit.