Arch. Hist. Exact Sci. 54 (2000) 421–454. © Springer-Verlag 2000

Eclipse Prediction in Mesopotamia

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Communicated by A. JONES

Introduction

Among the many celestial events observed in Ancient Mesopotamia, eclipses, particularly eclipses of the moon, were considered to be among the most astrologically significant. More than eight of the seventy or so tablets of the great astronomical omen series *Enūma Anu Enlil* are devoted to their interpretation,[1] and a number of rituals to be performed during an eclipse are known from the Neo-Assyrian, Achaemenid and Hellenistic periods.[2] It is perhaps not surprising, therefore, that attempts were made to predict eclipses. Indeed it may have been the time that was needed to prepare for the eclipse rituals which provided one of the earliest motivations for eclipse prediction in Mesopotamia, although this is not to suggest that by predicting an eclipse in advance its ominous meaning would be changed.[3]

Our earliest contemporary records of eclipse observations from Mesopotamia come from the first half of the seventh century BC, although records stretching back to the middle of the eighth century are preserved in later compilations. These accounts are given in the various Letters and Reports sent by Assyrian and Babylonian scholars to the Assyrian court. It is evident from these accounts that primitive attempts were being made to predict the eclipses before they were observed. In Babylon, by at least the middle of the seventh century BC, and we have good reason to believe stretching back to as early as

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[1] Those tablets of *Enūma Anu Enlil* concerned with lunar eclipses have been edited by F. Rochberg-Halton, *Aspects of Babylonian Celestial Divination: The Lunar Eclipse Tablets of Enūma Anu Enlil*, Archiv für Orientforschung Beiheft 22 (Horn, 1988).

[2] The Substitute King Ritual is discussed by S. Parpola, *Letters from Assyrian Scholars to the Kings Esarhaddon and Assurbanipal, Part II: Commentary and Appendices,* Alter Orient und Altes Testament 5/2 (Neukirchen-Vluyn, 1983), xxii–xxxii, and J. Bottéro, *Mesopotamia: Writing, Reasoning, and the Gods* (University of Chicago Press, Chicago, 1992), 138–155. For examples of texts describing rituals involving the playing of a kettledrum, see P.-A. Beaulieu and J. P. Britton, "Rituals for an Eclipse Possibility in the 8th Year of Cyrus," *Journal of Cuneiform Studies* 46 (1994), 73–86, and D. Brown and M. Linssen, "BM 134761 = 1965-10-14, 1 and the Hellenistic Period Eclipse Ritual from Uruk," *Revue d'Assyriologique et d'Archéologie Orientale* (forthcoming).

[3] By contrast, in China if an event was predicted before it occurred then its significance as an omen was reduced. See N. Sivin, "Cosmos and Computation in Early Chinese Mathematical Astronomy," *T'oung Pao* 55 (1969), 1–73.

the middle of the eighth century,[4] astronomical observations were being systematically conducted and recorded in a group of texts which we have come to call the Astronomical Diaries. These Diaries, and other texts which are related to them, contain many observations and predictions of eclipses. The predictions generally include the expected time of the eclipse, apparently calculated quite precisely. By the last three centuries BC, the Babylonian astronomers had developed highly advanced mathematical theories of the moon and planets. This lunar theory could be used to calculate the times and magnitudes of lunar and solar eclipses.

In this paper I shall outline the various methods which appear to have been formulated by the Mesopotamian astronomers to predict eclipses of the sun and moon. This will lead into the question of which of these methods were actually used, and why. However, before proceeding along this path, it is necessary to first make some remarks concerning general methods of eclipse prediction.

General methods of eclipse prediction

With respect to the fixed background of stars, the moon moves around the Earth in an approximately circular orbit with an average period of 27.3216 days, known as the sidereal month. However, from the Earth the sun also appears to circle us returning to the same location relative to the fixed stars in a period of 365.2564 days, known as the sidereal year. Therefore, over the course of a sidereal month the sun has moved slightly ahead of the fixed stars, and so it takes a little more than another 2 days for the moon and sun to reach conjunction. The average time interval between two conjunctions or oppositions of the moon and sun is equal to 29.5306 days and is known as the synodic month.[5]

There are two types of eclipses: lunar and solar. Lunar eclipses occur when the moon at opposition passes through the Earth's shadow, whereas solar eclipses may occur whenever the moon at conjunction covers some part of the suns disc.[6] If the two planes in which the moon and sun move were the same then one luminary would be eclipsed every conjunction or opposition. However, these two planes are in fact inclined at an angle of about 5° to one another, intersecting at points called nodes. The average

[4] See A. Sachs, "Babylonian Observational Astronomy," *Philosophical Transactions of the Royal Society of London* 276 (1974), 43–50.

[5] It is worth noting that while we have no evidence that the Babylonians possessed a physical theory of eclipses, all of the concepts used in the following discussion (syzygy, nodes, anomaly, etc.) were, or became, familiar to them.

[6] The situation for solar eclipses is complicated by the fact that, due to the relative sizes of the Earth, moon and sun, the moon's umbral shadow only falls on a small part of the Earth's surface. Thus the prediction of solar eclipses for any given site requires knowledge of the geometry of the Earth-moon-sun system, and of the geographical location on the Earth's surface of the observation site. There is no evidence that the Babylonian astronomers were able to take this into account. Instead, I agree with Aaboe in suggesting that the Babylonians may have been content to distinguish between those conjunctions at which solar eclipses were *possible*, and to exclude those at which they were not. See A. Aaboe, "Remarks on the Theoretical Treatment of Eclipses in Antiquity," *Journal for the History of Astronomy* 3 (1972), 105–118.

interval between successive passages of the moon by a given node, known as a dracontic month, is equal to 27.2122 days. Only when the Earth's shadow at opposition (for a lunar eclipse) or when the sun at conjunction (for a solar eclipse) is near to a node will an eclipse be possible. This is equivalent to saying that eclipses only occur when the latitude of the moon is sufficiently close to zero at the moment of conjunction or opposition. Due to the different lengths of the synodic and dracontic months, the lunar node recedes in longitude by about 1;34° per month.[7] During this same month, the sun on average travels about 29;6° forward in longitude. Therefore, the difference in longitude between the node and the sun (or the Earth's shadow) at syzygy increases by roughly 30;40° per month. If we assume that eclipses do not occur in consecutive months, as it is apparent that the Babylonian astronomers did, it is possible to define an "eclipse possibility" as the syzygy at which the Earth's shadow or the sun is closest to the node every time it passes by that node. The average interval between successive eclipse possibilities is equal to about 5;52,7,44 months.[8] Of course, this does not imply that eclipses possibilities occur every 5;52,7,44 months, for then moon and sun would not be at syzygy, but rather that eclipses occur every six months, with a five month interval every now and again.

This rule that eclipses can be predicted by simply moving on by 6 or occasionally 5 lunar months from the preceding eclipse possibility is the most basic scheme for calculating eclipses that can be identified. Its use is complicated by the uncertainty as to when the 5 month interval is needed. However, once the months of eclipse possibilities have been identified it is even possible to make a rough estimate of the time of the expected eclipses by measuring the time interval during which the moon and sun had been seen together on the days running up to syzygy. It is easy to see how such a basic method would work. On the expected day of an eclipse the latitude of the moon must be close to zero. To a first approximation, therefore, the time interval during which the moon and sun were both above the horizon on the last evening before opposition or conjunction is dependent upon the difference in longitude between the sun and the moon.[9] As the moment of syzygy occurs when this difference in longitude is either 0° or 180°, clearly if the time interval is great then syzygy is far off and may occur during the following day when the moon is below the horizon, whereas if it is small then the syzygy is close by and will occur during the night.

To predict eclipses more reliably, one must use one of two basic methods. The first is to calculate the latitude of the moon at every syzygy and then to declare that those with the latitude closest to zero are eclipse possibilities; this is the basis of the method used in the Babylonian mathematical astronomy of the Seleucid period. However, to do so

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7 Here and elsewhere I am transcribing sexagesimal numbers using commas to separate places and a semicolon to separate integers from fractions.

8 I am here following the discussion given by J. P. Britton, "An Early Function for Eclipse Magnitudes in Babylonian Astronomy," *Centaurus* 32 (1989), 1–52. For further details I refer the reader to his article.

9 More generally, this time interval is a very complicated function dependent upon a number of factors including the moon's longitude, latitude and velocity, and the visibility conditions. See O. Neugebauer, *The Exact Sciences in Antiquity* (Brown University Press, Providence, 1957), 107–110, and L. Brack-Bernsen and O. Schmidt, "On the Foundations of the Babylonian Column Φ: Astronomical Significance of Partial Sums of the Lunar Four," *Centaurus* 37 (1994), 183–209.

requires a lunar theory capable of calculating latitudes for every conjunction and opposition. Before the development of such a theory, early astronomers had to rely on simpler schemes which made use of the periodicities in the moon's motion. Let me discuss the case for lunar eclipses; solar eclipse possibilities can be treated analogously. Once an eclipse has occurred, it is clear from the rules discussed above that another eclipse will take place when (a) the moon is in the same phase again, and (b) the moon is at its same position in its orbit with respect to the node. In other words, an eclipse will occur after there has been both a whole number of synodic months and a whole number of draconitic months. Although there is no reasonably small integral common multiple for these two intervals, a number of short periods are close. For example, 47 synodic months is only one tenth of a day different from 51 draconitic months, and 135 synodic months is about half a day more than 146 draconitic months. The most useful of these periods, however, is 223 synodic months, which is very close to 242 draconitic months. This period is useful because it is also very close to 239 anomalistic months,[10] which means that the recurring eclipses will have similar magnitudes and durations. This period, which is equal to about 6585 1/3 days or slightly more than 18 years, has become known as the "Saros."[11] Its excellence in predicting eclipses is illustrated by Table 1 which lists, for three groups of eclipses, the magnitudes and local times of first contact for Babylon and the differences between the circumstance of each eclipse and its predecessor one Saros before.[12] The first series is about as poor as the Saros gets, whereas the second is about the best. Evidently, there is some variation in the stability of the Saros between the three groups, but in general the magnitude changes by less than about 0.1 of the lunar diameter for each eclipse, and the local time increases by approximately 8 hours per eclipse. The average interval between eclipse possibilities in the Saros is 5;52,6,18, quite close to the theoretical value of 5;52,7,44. A period with an even closer approximation to the theoretical value of the average eclipse interval is given by combining the 135 and 223 month periods to obtain 358 synodic months yielding 5;52,7,52.[13] However, there is a relatively large variation in lunar anomaly between successive eclipses separated by this period and so it is of little or no use for predicting the time of an eclipse.

It will be useful at this point to define a number of terms that I shall use when discussing the Saros. By "Saros cycle," I mean the period of 223 synodic months containing 38 eclipse possibilities. By "Saros series," I am referring to a collection of eclipse possibilities each separated by one Saros of 223 synodic months from the preceding eclipse possibility. A "Saros scheme" will be taken to mean the particular distribution of eclipse possibilities within a Saros cylce at a given time.

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[10] Because the moon's orbit is not exactly circular its distance from the Earth varies. The average interval between successive closest approaches to the Earth is known as an anomalistic month and is equal to 27.5545 days.

[11] As has often been noted, the term "Saros" is modern. To the Babylonians this period was simply called 18 MU.MEŠ "18 years." See O. Neugebauer, *The Exact Sciences in Antiquity* (Brown University Press, Providence, 1957), 141–143 for a history of the term "Saros."

[12] Throughout this paper, magnitudes are given as a fraction of the lunar or solar diameter, and local times in hours and decimals.

[13] For details of these eclipse periods, see J. P. Britton, "An Early Function for Eclipse Magnitudes in Babylonian Astronomy," *Centaurus* 32 (1989), 1–52.

Table 1. Three Sample Saros Series

Cycle	Date	Magnitude	Δ Magnitude	Local Time	Δ Local Time
1	−746 Feb 6	0.92		2.37	
2	−728 Feb 17	0.86	−0.06	9.80	7.43
3	−710 Feb 27	0.77	−0.09	17.13	7.33
4	−692 Mar 10	0.67	−0.10	0.33	7.20
5	−674 Mar 21	0.56	−0.11	7.43	7.10
6	−656 Mar 31	0.44	−0.11	14.44	7.01
1	−536 Oct 17	1.50		5.70	
2	−518 Oct 28	1.48	−0.02	13.82	8.12
3	−500 Nov 7	1.47	−0.01	22.03	8.21
4	−482 Nov 19	1.47	−0.00	6.29	8.26
5	−464 Nov 29	1.46	−0.01	14.55	8.26
6	−446 Dec 11	1.46	−0.00	22.80	8.25
1	−218 Sep 12	0.78		10.56	
2	−200 Sep 22	0.73	−0.05	18.35	7.79
3	−182 Oct 4	0.69	−0.04	2.31	7.96
4	−164 Oct 14	0.66	−0.03	10.40	8.09
5	−146 Oct 25	0.64	−0.02	18.62	8.22
6	−128 Nov 5	0.62	−0.02	2.90	8.28

Eclipse predictions in the Assyrian and Babylonian letters and reports

Among the many cuneiform tablets recovered from the site of Nineveh were a large number of letters and reports sent by Assyrian and Babylonian scholars to the kings Esarhaddon and Assurbanipal. These probably all date from within the period −673 to −644 and contain the earliest series of celestial observations from Mesopotamia preserved in a contemporary source.[14] The letters sent by the scholars to the Assyrian court were written on various matters, often including astronomical observations and predictions and their astrological interpretation.[15] The astrological reports were sent to the kings by the specialists in divination whenever they made an observation or a prediction.[16] These reports often simply contain a quotation from the omen series *Enūma Anu Enlil*;

[14] Earlier astronomical records are preserved from Babylon, but, with the exception of a single diary from 652 BC, they are all contained in compilations which were probably made at a later date.

[15] The letters have been edited most recently by S. Parpola, *Letters from Assyrian and Babylonian Scholars* (Helsinki University Press, Helsinki, 1993). All translations of the letters will be taken from this edition and quoted by their LABS number. This is a revised version of Parpola's earlier edition, *Letters from Assyrian Scholars to the Kings Esarhaddon and Assurbanipal, Part I: Texts*, Alter Orient und Altes Testament 5/1 (Neukirchen-Vluyn, 1970). See also his commentary *Letters from Assyrian Scholars to the Kings Esarhaddon and Assurbanipal, Part II: Commentary and Appendices*, Alter Orient und Altes Testament 5/2 (Neukirchen-Vluyn, 1983).

[16] The reports have been edited most recently by H. Hunger, *Astrological Reports to Assyrian Kings* (Helsinki University Press, Helsinki, 1992). All translations of the reports will be taken from this edition and quoted by their ARAK number. This edition supersedes R. C. Thompson,

however, this is sufficient for it to be inferred that the observation was made, for the protasis of a celestial omen always implies an observation.[17]

A number of the letters and reports describe eclipses of the sun or moon. Sometimes these have been observed, but on a significant number of occasions they relate to eclipses that were predicted and then not seen. For example, the letter LABS 135 sent by Babu-šumu-iddina to the king tells of how he watched for the moon to be eclipsed but did not see it:

> To the king, my lord: you servant Babu-šumu-iddina. Good health to the king, my lord! May Nabū and Marduk very greatly bless the king, my lord! Concerning the watch about which the king, my lord, wrote to me, neither the moon nor the eclipse were seen. May they appoint a guardian of [he]alth and life for the king, my lord! On the 15th day the god appeared with the god.

The letter seems to imply that on this occasion the eclipse was not seen because the moon was obscured, probably on account of clouds. The following morning, the moon and the sun (the gods Sin and Šamaš) were seen together in the sky, meaning that the moment of opposition had passed and it was no longer necessary to watch for the eclipse. In other letters and reports, however, it is clear that the eclipse simply did not occur when it was expected. This may be because the eclipse passed by during the hours when the luminary was below the horizon, or that on the expected date the prediction failed.

Only a small amount of information is given in the letters and reports themselves about how the eclipse predictions were made. In some cases the eclipses were not "predicted" in an astronomical sense at all, but rather foretold by other ominous events. For example, eclipses could be predicted by liver- or oil-divination, by halos, by the new moon appearing too early, or by fog.[18] In other cases, however, it is clear that attempts were being made to predict eclipses astronomically. For example, the report ARAK 502 and others indicate that lunar and solar eclipses were generally expected to take place within a month of one another:

> . . . An eclipse of the moon and sun in Sivan (III) will take place. These signs are of bad fortune for Akkad, for the kings of Westland and of Akkad; and now, in this month of Kislev (IX), an eclipse will take place. . . .

This report appears to have been written in the 9th month of a year. During this month an eclipse was expected to take place. Six months later, in the 3rd month of the following year, both a lunar and a solar eclipse were expected. In addition to indicating that lunar and solar eclipses were expected to occur in the same month, this report also implies that the six month interval between eclipse possibilities had been identified. Other texts, for example LABS 45 indicate that occasionally two successive months were considered as possible dates for an eclipse:

The Reports of the Magicians and Astrologers of Nineveh and Babylon in the British Museum (London, 1900).

[17] H. Hunger, *Astrological Reports to Assyrian Kings* (Helsinki University Press, Helsinki, 1992), xvi.

[18] See U. Koch-Westenholz, *Mesopotamian Astrology* (Museum Tusculanum Press, Copenhagen, 1995), 105.

> . . . Concerning the watch of the sun about which the king, my lord, wrote to me, it is (indeed) the month for a watch of the sun. We will keep the watch twice, on the 28th of Marchesvan (VIII) and the 28th of Kislev (IX). Thus we will keep the watch of the sun for 2 months. . . .

This suggests that the scholars had realized that not only are eclipses separated by 6, 12, 18 etc. months possible, but also those at 5, 11, 17 etc. months. In other words, eclipse possibilities are separated not only by 6n months (where n is an integer less than about 9), but also by 6n − 1 months. Only one letter (LABS 71 which discusses lunar eclipses) makes any reference to this rule and, unfortunately, it is somewhat damaged:

> . . . [Eclipses] cannot occur [dur]ing certain periods. [After] ⌈4⌉ months, there was a watch in Marchesvan (VIII), and now, in the month Kislev (IX) we will (again) keep watch. . . .

The mention of 4 months is confusing. However, in his transliteration Parpola notes that the "4" is damaged and indeed in his earlier edition of this text had been unable to read any number here. From the sketch noting his collation of this text it is not clear what this reading should be, but one would expect "5" in order for the text to make any kind of sense astronomically.[19] The text would therefore seem to suggest that both the 8th and 9th months were considered as eclipse possibilities respectively five and six months after an eclipse possibility in the 3rd month.

The realization that eclipse possibilities can occur at a five month interval is also implied by the report ARAK 4 which reports an observation of an eclipse at an "unappointed time" (*ina la mi-na-ti-šú*). A commentary on the omen explains the meaning of "unappointed time":

> If the moon is eclipsed at an unappointed time, (it means that either) the six months have not yet passed (since the preceding eclipse), or alternatively an eclipse occurs on the 12th or 13th day.[20]

It would appear from the quoted examples that, in general, the scholars were unsure as to when a 5 month interval might occur. One way to eliminate this problem would be to use eclipse periods such as the Saros discussed above. Indeed, Parpola writes that "in addition to the rule of thumb that the moon may be eclipsed every sixth synodic month, the scholars of this period certainly had recognized the 47-month eclipse period and probably also the 18-year Saros."[21] However, from the preserved texts I do not think it is possible to make this conclusion. To do so, one would need to try to find patterns

[19] Christopher Walker has since examined the tablet and confirmed that a reading of 5 is quite possible.

[20] *ACh. Sin* 3, 26. See F. X. Kugler and J. Schaumberger, *Sternkunde und Sterdienst in Babel. Ergänzungen III* (Aschendorffsche Verlagsbuchhandlung, Münster, 1935), 251, and F. Rochberg-Halton, *Aspects of Babylonian Celestial Divination: The Lunar Eclipse Tablets of Enūma Anu Enlil*, Archiv für Orientforschung Beiheft 22 (Horn, 1988), 41 on which my translation is based.

[21] Parpola, *Letters from Assyrian Scholars to the Kings Esarhaddon and Assurbanipal, Part II: Commentary and Appendices*, Alter Orient und Altes Testament 5/2 (Neukirchen-Vluyn, 1983), 51. The use of the 47-month eclipse period by the Assyrian scholars was also claimed by B. L. van der Waerden, *Science Awakening II: The Birth of Astronomy* (Noordhoff, Leiden, 1974), 118–119.

in the dates of the eclipse predictions, but it many cases it is not possible to date those texts concerned.[22] It may well be that these eclipse periods were in use, but we do not have the evidence to be certain.[23]

Once the months of the eclipse possibilities have been established, the next question facing the scholars was to decide the day of the eclipse and whether it would be seen, or would "pass by" (or be "omitted") when the luminary was below the horizon. In some texts the scholars were obviously uncertain as to the answer to this question, but in others it would seem that, at least for lunar eclipses, they were even able to predict the watch during which it would occur.[24] The approximate time of the expected eclipse was apparently determined by observing whether the moon and sun were visible together on the previous few days. For example, the report ARAK 42 notes that:

> The moon will be seen [together with] the sun in Elul (VI) on the 15th day, it will let [the eclip]se pass by. . . . it will not make (it). From Nabū-ahhe-eriba. [Elu]l (VI), 13th day.

As I have discussed in the preceding section, such observations can be used to make a rough estimate of the time of the eclipse. In the Babylonian Astronomical Diaries measurements of this time interval and five other similar intervals were systematically recorded each month.[25]

Eclipse predictions in the Late Babylonian astronomical texts

The large number of astronomical tablets recovered from Babylon reflect a much greater diversity of date an content than the Assyrian texts described above. They may be split into two main categories: texts of mathematical astronomy which have become known as ACT texts,[26] and texts of non-mathematical astronomy, known as NMAT

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[22] The dates proposed by Parpola in *Letters from Assyrian Scholars to the Kings Esarhaddon and Assurbanipal, Part II: Commentary and Appendices*, Alter Orient und Altes Testament 5/2 (Neukirchen-Vluyn, 1983) for many of the texts containing only eclipse predictions cannot be justified. See, for example, S. De Meis and H. Hunger, *Astronomical Dating of Assyrian and Babylonian Reports* (Istituto Italiano per l'Africa e l'Oriente, Rome, 1998) and D. R. Brown, *Neo-Assyrian and Neo-Babylonian Planetary Astronomy-Astrology (747–612 BC)* (Styx, forthcoming), Appendix 2.

[23] It may eventually be possible to determine whether eclipse periods were being used by the scholars, but first it will be necessary to systematically redate all of the letters. This is no small task and it would take me far beyond the scope of this article to even attempt to redate those letters including references to eclipses.

[24] In *Enūma Anu Enlil* the omen associated with an eclipse depends in part upon the watch (a third of a day or night) in which it took place. Since the eclipses were being reported for divination there was no need for the scholars to record the time of the eclipse more precisely.

[25] These are the so called "Lunar Six" described by A. Sachs, "A Classification of the Babylonian Astronomical Tablets of the Seleucid Period," *Journal of Cuneiform Studies* 2 (1948), 271–290.

[26] The ACT texts have largely been published by O. Neugebauer, *Astronomical Cuneiform Texts* (Lund Humphries, London, 1955). For references to texts published subsequently (mostly by Aaboe, Neugebauer and Sachs), see O. Neugebauer, *A History of Ancient Mathematical*

texts.[27] This study will be primarily concerned with the NMAT texts, so it will be useful here to briefly outline the main types of NMAT text.[28]

The fundamental observational text of the Babylonian astronomers[29] was the Astronomical Diary.[30] These texts typically contain a day by day account of the observations made over a six or seven month period. They include data on the length of the month, measurements of the lunar six, the passing by of the Normal Stars by the moon, eclipses, planetary phases, solstices and equinoxes, Sirius phenomena and occasionally events such as comets and meteors. Most of the contents of the Diaries represent observations; however, where observations were unavailable, for example because of bad weather or because an event was expected to occur at a moment when the heavenly body was below the horizon, then predictions were entered in their place. In addition, some data recorded in the Diaries, such as solstices and equinoxes, were always predicted. Surviving Diaries range in date from −651 to −60, although we have reason to believe that the Diary tradition began at least one hundred years earlier.

From the Diaries, the Babylonians appear to have abstracted records to compile two further types of texts: Goal-Year texts and texts devoted to individual phenomena. It will suffice here to state that the Goal-Year texts contain, among other things, descriptions of eclipse observations and predictions from eighteen years earlier that were to be

Astronomy (Springer-Verlag, Berlin, 1975). When discussing the ACT texts I will follow the terminology established by Neugebauer and assume some knowledge of the methods of Babylonian mathematical astronomy.

[27] The term NMAT (Non-Mathematical Astronomical Texts) was coined by A. Aaboe, “Observation and Theory in Babylonian Astronomy,” *Centaurus* 24 (1980), 14–35.

[28] These descriptions are based upon those given by A. Sachs, “A Classification of the Babylonian Astronomical Tablets of the Seleucid Period,” *Journal of Cuneiform Studies* 2 (1948), 271–290 and “Babylonian Observational Astronomy,” *Philosophical Transactions of the Royal Society of London* 276 (1974), 43–50, and H. Hunger, “Non-mathematical Astronomical Texts and Their Relationships,” in N. M. Swerdlow (ed.) *Ancient Astronomy and Celestial Divination* (The MIT Press, Cambridge, forthcoming). For further details I refer the reader to these articles. Most of the extant texts have been catalogued by A. J. Sachs, *Late Babylonian Astronomical and Related Texts* (Brown University Press, Providence, 1955). Copies of many of these tablets drawn by T. G. Pinches and J. N. Strassmaier were published in this work.

[29] The identity of the Babylonian astronomers is not fully known. In the Hellenistic period at least they held the title *ṭupšar Enūma Anu Enlil* “Scribe of (the great omen series) Enūma Anu Enlil” and were employed in the Esagila temple as astrologer-astronomers. See F. Rochberg, “The Cultural Locus of Astronomy in Late Babylonia,” in H. D. Galter (ed.), *Die Rolle der Astronomie in den Kulturen Mesopotamiens* (Grazer Morgenländische Studien, Graz, 1993), 31–45. A number of modern terms have been adopted to describe these individuals – none of which are very satisfactory – including “scribe,” “astrologer,” and “astronomer.” For convenience I will use “astronomer,” with the proviso that the astrological roles of these individuals are not forgotten.

[30] All of the dateable Diaries have been published by A. J. Sachs and H. Hunger, *Astronomical Diaries and Related Texts from Babylon, Volumes I-III* (Österreichischen Akademie der Wissenschaften, Vienna, 1988–1996). Translations of Diaries will be quoted from this work.

used in making predictions for a specific “Goal-Year,”[31] and that the texts of individual phenomena include many texts devoted to eclipses that I shall refer to as “Eclipse Texts.”[32] These Eclipse Texts may take one of three forms: simple lists of successive eclipse observations and predictions, lists arranged in Saros cycles, or individual reports of particular eclipse observations.

The source of the predictions found in the Diaries may have been the Almanacs and the Normal Star Almanacs. These texts contain predictions for a coming year of many of the phenomena that are to be found in the Diaries. Together with the Diaries they may also have been the source of the astronomical data recorded in a group of texts known as Horoscopes.[33] Finally, we have a group of texts I will term “Theoretical Texts.” These texts contain, for example, the dates of specific phenomena such as eclipse possibilities.

If we ignore, for the moment, the theoretical texts then all of the NMAT described above include references to eclipses of the sun and moon. As we would expect, the Diaries, Goal-Year texts and the Eclipse texts contain references to both observed and predicted eclipses, whereas the Almanacs and Normal Star Almanacs contain only predictions. It is not always clear whether the Horoscopes refer to observations or predictions, but at least in some cases they must be predictions. As a general rule, eclipse predictions can be distinguished from observations by the terminology used: *sin* AN-KU$_{10}$ denotes an observed eclipse of the moon, whereas the opposite order, AN-KU$_{10}$ *sin*, refers to a predicted lunar eclipse (for solar eclipses *sin* is replaced by *šamáš*).[34] Furthermore, predicted eclipses are usually described as being *šá* DIB meaning that they would be omitted when the luminary was below the horizon, or *ki* PAP NU IGI meaning “watched for, but not seen” when the anticipated eclipse failed to appear. Often accompanying the prediction of the eclipse is a time given relative to sunrise or sunset. As I have shown elsewhere, this time relates to the moment that the eclipse was

[31] The eclipse records in the Goal-Year texts, together with many of the records from the Diaries and the Eclipse Texts, have been edited by P. J. Huber, *Babylonian Eclipse Observations: 750 BC to 0* (Unpublished manuscript, 1973).

[32] These texts of individual phenomena will shortly be published by A. J. Sachs and H. Hunger, *Astronomical Diaries and Related Texts from Babylon, Volume V* (Österreichischen Akademie der Wissenschaften, Vienna, forthcoming).

[33] The Horoscopes have been published by F. Rochberg, *Babylonian Horoscopes*, Transactions of the American Philosophical Society 88/1 (Philadelphia, 1998).

[34] The first discussion of this terminology was, I believe, by F. X. Kugler, “Zur Erklärung der Babylonischen Mondtafeln I: Mond- und Sonnenfinsternisse,” *Zeitschrift für Assyriologie* 15 (1906), 178–209. More recently, see A. J. Sachs and H. Hunger, *Astronomical Diaries and Related Texts from Babylon, Volume I* (Österreichischen Akademie der Wissenschaften, Vienna, 1988), 23.

expected to begin.[35] This is important in establishing how the predicted times were calculated, as I shall discuss later.

In the following discussion it will be useful to split the problem of establishing how the Babylonian astronomers predicted eclipses into two related parts: determining the date of the eclipse possibilities, and calculating the time that the eclipse was expected to begin. I shall begin by discussing the first of these points, initially considering the case for lunar eclipses, but first let me remark that it seems reasonable to suppose that the predictions contained in all of the various different classes of NMAT for any particular period were made using the same method. We have only a small number of predictions that are contained in two different sources, but in every case the details of the eclipses, so far as they are recorded and preserved, are in agreement. Furthermore, we have no examples of eclipses predicted in an Almanac or a Normal Star Almanac where there is not either the same prediction or a corresponding observation recorded in a surviving Diary. It is possible, however, that some of the early (8th century BC) predictions recorded in the Eclipse Texts were calculated at a later date; if this were not the case then we are in the rather unsatisfactory situation of having a significantly further developed theory of eclipse prediction in Babylon of the mid-eighth century BC than in Assyria one hundred years later.

I have already discussed how the Assyrians seem to have realized that eclipse possibilities were separated by six or occasionally five month intervals. To reliably predict eclipses, the Babylonian astronomers needed to formulate a scheme to determine when these five month intervals were required. Commencing in the middle of the eighth century BC it seems that a more or less complete record of observed lunar eclipses was available to the Babylonian astronomers. Britton has shown that by a fairly basic analysis of this observational record, simple schemes for the arrangement of the five and six month intervals could be identified.[36] The most important of these is the Saros of 223 months. Within each Saros cycle there are 38 eclipse possibilities, 33 of which are separated by six month intervals, and the remaining 5 by five month intervals. Using the simple rule that these should be distributed as evenly as possible we get the following arrangement: if the first eclipse in a Saros cycle comes five months after the preceding eclipse possibility, then it will be followed by seven eclipses (nos. 2–8) each of which is

[35] J. M. Steele and F. R. Stephenson, “Lunar Eclipse Times Predicted by the Babylonians,” *Journal for the History of Astronomy*, 28 (1997) 119–131 and J. M. Steele, “Solar Eclipse Times Predicted by the Babylonians,” *Journal for the History of Astronomy*, 28 (1997) 131–139. In the first of these papers I speculated that one motivation for predicting the time of the beginning of the eclipse, rather than the moment of syzygy, was that if the prediction was to be used for religious purposes then it seems likely that the moment when the eclipse would begin would be the most useful time to predict. This has now been confirmed by the description of an eclipse ritual on BM 134761 which explains that the period of ritual lamentation during an eclipse begins at the moment of first contact and continues until the middle of the eclipse. See D. Brown and M. Linssen, “BM 134761 = 1965-10-14, 1 and the Hellenistic Period Eclipse Ritual from Uruk,” *Revue d’Assyriologique et d’Archéologie Orientale* (forthcoming).

[36] J. P. Britton, “An Early Function for Eclipse Magnitude in Babylonian Astronomy,” *Centaurus* 32 (1989), 1–52. See also O. Neugebauer, *A History of Ancient Mathematical Astronomy* (Springer-Verlag, Berlin, 1975), 504–505.

six months after the preceding eclipse, then an eclipse (no. 9) at five months, six more (nos. 10–15) at six months, another (no. 16) at five months, seven (nos. 17–23) at six months, another (no. 24) at five months, six at six months (nos. 25–30), one more at five months (no. 31), and finally seven (nos. 32–38) at six months. Thus the 38 eclipse possibilities are divided into five groups, each of which begins with an eclipse possibility five months after the preceding eclipse, containing eight, seven, eight, seven, and eight eclipses respectively. This is often written as 8-7-8-7-8. Of course, the definition of the beginning of the Saros period is arbitrary, and the distribution could equally well be 7-8-7-8-8, 8-7-8-8-7, 7-8-8-7-8 or 8-8-7-8-7. The last distribution is that found by Aaboe from a theoretical analysis of eclipse possibilities equally spaced in longitude.[37] That such arrangements were recognized by the Babylonian astronomers is proven by a number of tablets such as the "Saros Canon" (LBAT 1428) and the Eclipse Texts LBAT *1414, LBAT 1415 + 1416 + 1417, and LBAT *1419 which are all laid out in a format based upon this distribution of eclipse possibilities. These texts were all written sometime after the middle of the fourth century BC but refer to dates stretching back to −730. However, the preserved part of the text LBAT *1420 contains eclipse observations and predictions from −603 to −575 which also follow the 8-7-8-7-8 arrangement of eclipse possibilities, and this text was probably compiled not long after its final entry in −575, thus indicating that the Saros was in use by this period. Temple documents describing the ritual performed in anticipation of an eclipse that did not occur in the eighth year of Cyrus also imply that the Saros was in use by at least the sixth century BC.[38]

Once the 8-7-8-7-8 scheme had been identified, the next problem facing the Babylonian astronomers was to decide when to begin the scheme (in other words, which eclipse possibility was to be defined as no. 1). Evidence for their solution to this problem comes from the records themselves. The texts LBAT *1414, LBAT 1415 + 1416 + 1417, and LBAT *1419 all appear to come from a large compilation of eclipse records that probably originally stretched from −746 to −314.[39] Running through these texts is the expected 8-7-8-7-8 grouping of eclipses, and where an eclipse is predicted at a five month interval, the record will explicitly state 5 ITU "5 months." Unfortunately, however, these texts are somewhat fragmentary and so do not fully define the placing of the five month intervals. Following a suggestion by Christopher Walker, therefore, I have attempted to reconstruct this compilation by supplementing the records contained in it with those preserved in other NMAT sources.[40] The results are shown in columns 1–24 of Table 2.

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[37] A. Aaboe, "Remarks on the Theoretical Treatment of Eclipses in Antiquity," *Journal for the History of Astronomy* 3 (1972), 105–118.

[38] P.-A. Beaulieu and J. P. Britton, "Rituals for an Eclipse Possibility in the 8th Year of Cyrus," *Journal of Cuneiform Studies* 46 (1994), 73–86.

[39] 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* (British Museum Press, London, 1997), 17–25. A full discussion of the structure and layout of all the Eclipse Texts is given in my appendix to A. J. Sachs and H. Hunger, *Astronomical Diaries and Related Texts from Babylon, Volume V* (Österreichischen Akademie der Wissenschaften, Vienna, forthcoming).

[40] These dates have been taken from the list of eclipse records in J. M. Steele, *Observations and Predictions of Eclipse Times by Early Astronomers* (forthcoming), Appendix 1.

In this table, dates of eclipses which were (at least partly) visible in Babylon are indicated in bold.[41] There is no distinction between dates of eclipses not visible because they occurred during the daytime, and those dates when there was no umbral eclipse. Dates of eclipse possibilities for which we have a record in an NMAT source are underlined, and those where we have an explicit statement of the five month interval are in italics (a number of other five month intervals are implicitly determined by the dates of the recorded eclipses). The layout of the five month intervals between groups of eclipses is illustrated by the empty rows in the table.[42] It should be noted that this distribution of the eclipse possibilities comes naturally from the observable eclipses in the very first column of the table. If one assumes that the first eclipse in a group is the first eclipse that is visible after an interval of 6n − 1 months from the preceding visible eclipse, and that the two groups containing only seven eclipse possibilities do not come immediately after one another, then there is no option but to choose the distribution given here.

Interestingly, there are no eclipse records between −746 and −314 that contradict this distribution of eclipse possibilities. Indeed, between −746 and −340 the scheme correctly predicts every eclipse that was visible in Babylon. On −339 September 29 and again on −321 October 20 a lunar eclipse occurred which was not predicted by this scheme. Instead, eclipses were predicted one month earlier. These are noted by an asterisk after the predicted date in the table. Both eclipses, however, had only very small magnitudes (0.10 and 0.13 respectively), and may not have been noticed by the Babylonian astronomers.[43] It would therefore seem that this scheme was used throughout the period from −746 to −314. Furthermore, extending the scheme for a further three cycles down to at least −278, there is still no disagreement between this scheme and the records of observed and predicted eclipses on the NMAT, although two more unpredicted eclipses (on −285 October 3 and −281 January 26) may have been visible. However, the evidence suggests that the scheme may have continued being used until at least −278.

There are two groups of theoretical texts which give information on the eclipse schemes of this period: the single tablet LBAT *1418; and a text which has become known as the "Saros Canon," LBAT 1428, together with two related texts LBAT *1422 + *1423 + *1424 and LBAT *1425.[44] Both of these two groups of texts contain calculations for earlier eclipses. LBAT *1418, which contains dates of eclipse possibilities from parts of the years between −646 and −573, appears to be based upon the same scheme as given in columns 1–27 of Table 2. The other group of texts, however, contain a variant scheme

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[41] In this and the following tables, dates of full and new moons have been taken from H. H. Goldstine, *New and Full Moons 1001 BC to AD 1651* (American Philosophical Society, Philadelphia, 1973).

[42] For columns 8 and 9 the tablet LBAT *1420 fully determines the layout of the table, but the important point is that by reconstructing the whole table as described above, we can see that this same layout extends beyond these two columns.

[43] The Diaries for those months are unfortunately not preserved, so we cannot be sure whether these two eclipses were observed or not.

[44] The Saros Canon and related texts have been published 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).

Table 2. Distribution of lunar eclipse possibilities over the Late Babylonian period

	1	2	3	4	5	6
1	***-746 Feb 6***	-728 Feb 17	**-710 Feb 27**	**-692 Mar 10**	-674 Mar 21	-656 Mar 31
2	**-746 Aug 2**	-728 Aug 12	**-710 Aug 23**	**-692 Sep 3**	-674 Sep 14	**-656 Sep 24**
3	**-745 Jan 26**	-727 Feb 5	**-709 Feb 16**	**-691 Feb 27**	-673 Mar 10	**-655 Mar 20**
4	**-745 Jul 22**	**-727 Aug 2**	-709 Aug 13	**-691 Aug 23**	**-673 Sep 4**	-655 Sep 14
5	-744 Jan 15	**-726 Jan 25**	**-708 Feb 6**	-690 Feb 16	**-672 Feb 27**	**-654 Mar 10**
6	-744 Jul 11	-726 Jul 22	-708 Aug 1	**-690 Aug 12**	-672 Aug 23	-654 Sep 3
7	-743 Jan 3	-725 Jan 15	-707 Jan 25	-689 Feb 6	-671 Feb 16	-653 Feb 27
8	-743 Jun 30	-725 Jul 11	-707 Jul 21	-689 Aug 2	-671 Aug 12	-653 Aug 23
9	**-743 Nov 25**	-725 Dec 6	**-707 Dec 16**	**-689 Dec 28**	-670 Jan 7	**-652 Jan 19**
10	**-742 May 20**	**-724 May 31**	-706 Jun 11	-688 Jun 21	**-670 Jul 2**	**-652 Jul 13**
11	**-742 Nov 14**	**-724 Nov 25**	-706 Dec 6	**-688 Dec 16**	**-670 Dec 28**	-651 Jan 7
12	**-741 May 10**	-723 May 20	**-705 May 31**	**-687 Jun 11**	-669 Jun 22	-651 Jul 2
13	**-741 Nov 3**	**-723 Nov 14**	-705 Nov 25	**-687 Dec 5**	**-669 Dec 17**	-651 Dec 27
14	-740 Apr 28	-722 May 10	-704 May 20	-686 May 31	**-668 Jun 11**	-650 Jun 22
15	-740 Oct 22	-722 Nov 3	-704 Nov 13	-686 Nov 24	-668 Dec 5	-650 Dec 16
16	**-739 Mar 20**	-721 Mar 31	**-703 Apr 10**	***-685 Apr 22***	*-667 May 2*	*-649 May 13*
17	**-739 Sep 12**	-721 Sep 23	**-703 Oct 3**	-685 Oct 15	-667 Oct 25	**-649 Nov 6**
18	-738 Mar 9	**-720 Mar 19**	**-702 Mar 31**	-684 Apr 10	**-666 Apr 21**	**-648 May 2**
19	**-738 Sep 1**	**-720 Sep 12**	-702 Sep 23	**-684 Oct 3**	**-666 Oct 15**	-648 Oct 25
20	-737 Feb 26	**-719 Mar 9**	**-701 Mar 20**	-683 Mar 30	**-665 Apr 10**	**-647 Apr 21**
21	-737 Aug 22	**-719 Sep 1**	**-701 Sep 13**	-683 Sep 23	**-665 Oct 4**	**-647 Oct 15**
22	-736 Feb 15	-718 Feb 26	-700 Mar 8	-682 Mar 19	-664 Mar 29	-646 Apr 10
23	-736 Aug 11	-718 Aug 22	-700 Sep 1	-682 Sep 13	-664 Sep 23	-646 Oct 4
24	-735 Jan 5	**-717 Jan 16**	**-699 Jan 27**	-681 Feb 7	**-663 Feb 17**	**-645 Mar 1**
25	**-735 Jul 1**	**-717 Jul 13**	-699 Jul 23	**-681 Aug 3**	**-663 Aug 14**	-645 Aug 25
26	**-735 Dec 25**	**-716 Jan 6**	**-698 Jan 16**	**-680 Jan 28**	-662 Feb 7	**-644 Feb 18**
27	**-734 Jun 21**	-716 Jul 1	-698 Jul 12	**-680 Jul 22**	**-662 Aug 3**	-644 Aug 13
28	-734 Dec 15	**-716 Dec 25**	-697 Jan 6	**-679 Jan 16**	**-661 Jan 28**	-643 Feb 7
29	-733 Jun 10	-715 Jun 20	-697 Jul 1	**-679 Jul 11**	-661 Jul 23	-643 Aug 2
30	-733 Dec 5	-715 Dec 15	-697 Dec 26	-678 Jan 6	-660 Jan 17	-642 Jan 27
31	**-732 Apr 30**	-714 May 11	**-696 May 21**	**-678 Jun 2**	-660 Jun 12	-642 Jun 23
32	-732 Oct 24	**-714 Nov 4**	**-696 Nov 15**	-678 Nov 26	**-660 Dec 6**	**-642 Dec 18**
33	**-731 Apr 19**	**-713 May 1**	-695 May 11	**-677 May 22**	**-659 Jun 2**	-641 Jun 13
34	-731 Oct 13	**-713 Oct 24**	**-695 Nov 4**	-677 Nov 15	**-659 Nov 25**	**-641 Dec 7**
35	-730 Apr 9	**-712 Apr 19**	**-694 May 1**	-676 May 11	**-658 May 22**	**-640 Jun 2**
36	**-730 Oct 2**	**-712 Oct 13**	-694 Oct 24	**-676 Nov 3**	**-658 Nov 15**	-640 Nov 25
37	-729 Mar 30	-711 Apr 9	-693 Apr 20	-675 Apr 30	-657 May 12	-639 May 22
38	-729 Sep 22	-711 Oct 2	-693 Oct 13	-675 Oct 24	-657 Nov 4	-639 Nov 15

that gives rise to eclipse possibilities on different dates, as shown in Table 3.[45] In other words, the month chosen as the first eclipse possibility in our 8-7-8-7-8 arrangement is different to that given in columns 1–27 of Table 2. This new scheme – I will call it

[45] In fact, the small fragment LBAT *1425 agrees with both of the two schemes.

Table 2. (Cont.)

	7	8	9	10	11	12
1	**-638 Apr 11**	**-620 Apr 22**	-602 May 3	-584 May 13	-566 May 25	-548 Jun 4
2	**-638 Oct 6**	-620 Oct 16	**-602 Oct 26**	**-584 Nov 7**	**-566 Nov 18**	**-548 Nov 29**
3	**-637 Apr 1**	-619 Apr 11	-601 Apr 22	**-583 May 2**	**-565 May 14**	-547 May 24
4	**-637 Sep 25**	**-619 Oct 6**	-601 Oct 17	**-583 Oct 27**	**-565 Nov 8**	-547 Nov 18
5	-636 Mar 20	**-618 Mar 31**	**-600 Apr 11**	-582 Apr 22	-564 May 2	**-546 May 14**
6	**-636 Sep 13**	**-618 Sep 25**	-600 Oct 5	**-582 Oct 16**	**-564 Oct 27**	-546 Nov 7
7	-635 Mar 10	-617 Mar 21	-599 Mar 31	-581 Apr 12	-563 Apr 22	-545 May 3
8	-635 Sep 2	-617 Sep 14	-599 Sep 24	-581 Oct 5	-563 Oct 16	-545 Oct 27
9	-634 Jan 29	**-616 Feb 9**	***-598 Feb 20***	-580 Mar 2	***-562 Mar 13***	**-544 Mar 24**
10	-634 Jul 24	**-616 Aug 3**	**-598 Aug 15**	-580 Aug 25	**-562 Sep 5**	**-544 Sep 16**
11	**-633 Jan 18**	**-615 Jan 29**	-597 Feb 9	**-579 Feb 19**	**-561 Mar 3**	-543 Mar 13
12	**-633 Jul 14**	-615 Jul 24	-579 Aug 4	**-579 Aug 15**	-561 Aug 26	-543 Sep 5
13	**-632 Jan 7**	**-614 Jan 18**	-596 Jan 29	**-578 Feb 8**	**-560 Feb 20**	-542 Mar 2
14	-632 Jul 2	**-614 Jul 14**	-595 Jul 24	-578 Aug 4	**-560 Aug 15**	-542 Aug 26
15	-632 Dec 26	-613 Jan 7	-595 Jan 17	-577 Jan 28	-559 Feb 8	-541 Feb 19
16	***-631 May 24***	-613 Jun 4	-595 Jun 14	*-577 Jun 25*	-559 Jul 9	-541 Jul 17
17	-631 Nov 16	**-613 Nov 27**	**-595 Dec 8**	-577 Dec 19	**-559 Dec 29**	**-540 Jan 10**
18	-630 May 13	-612 May 23	**-594 Jun 3**	**-576 Jun 14**	-558 Jun 25	-540 Jul 5
19	**-630 Nov 5**	**-612 Nov 16**	**-594 Nov 27**	**-576 Dec 8**	-558 Dec 19	**-540 Dec 29**
20	-629 May 2	-611 May 12	**-593 May 23**	**-575 Jun 3**	-557 Jun 14	**-539 Jun 24**
21	-629 Oct 26	**-611 Nov 5**	-593 Nov 17	**-575 Nov 27**	**-557 Dec 9**	-539 Dec 19
22	-628 Apr 20	-610 May 1	-592 May 12	-574 May 23	-556 Jun 2	**-538 Jun 13**
23	-628 Oct 15	-610 Oct 26	-592 Nov 5	-574 Nov 17	-556 Nov 27	-538 Dec 8
24	-627 Mar 11	**-609 Mar 22**	**-591 Apr 2**	-573 Apr 13	-555 Apr 23	**-537 May 5**
25	**-627 Sep 4**	**-609 Sep 16**	-591 Sep 26	-573 Oct 7	**-555 Oct 17**	-537 Oct 29
26	**-626 Mar 1**	-608 Mar 11	**-590 Mar 22**	**-572 Apr 2**	-554 Apr 13	**-536 Apr 23**
27	**-626 Aug 24**	**-608 Sep 4**	-590 Sep 15	-572 Sep 25	**-554 Oct 6**	**-536 Oct 17**
28	**-625 Feb 18**	**-607 Mar 1**	-589 Mar 12	**-571 Mar 22**	**-553 Apr 3**	-535 Apr 13
29	**-625 Aug 13**	**-607 Aug 24**	-589 Sep 4	**-571 Sep 14**	**-553 Sep 26**	-535 Oct 6
30	-624 Feb 8	-606 Feb 18	-588 Feb 29	-570 Mar 12	-552 Mar 22	-534 Apr 2
31	-624 Jul 4	-606 Jul 15	-588 Jul 25	-570 Aug 5	-552 Aug 16	-534 Aug 27
32	-624 Dec 28	**-605 Jan 8**	**-587 Jan 19**	-569 Jan 30	**-551 Feb 9**	**-533 Feb 21**
33	**-623 Jun 23**	**-605 Jul 5**	-587 Jul 15	-569 Jul 26	**-551 Aug 6**	-533 Aug 17
34	-623 Dec 17	**-605 Dec 28**	**-586 Jan 8**	-568 Jan 19	**-550 Jan 29**	**-532 Feb 10**
35	-622 Jun 13	-604 Jun 23	**-586 Jul 4**	**-568 Jul 15**	-550 Jul 26	**-532 Aug 5**
36	**-622 Dec 6**	**-604 Dec 17**	-586 Dec 28	**-567 Jan 7**	**-549 Jan 19**	-531 Jan 29
37	-621 Jun 2	-603 Jun 13	-585 Jun 24	-567 Jul 4	**-549 Jul 15**	**-531 Jul 26**
38	-621 Nov 26	-603 Dec 6	-585 Dec 18	-567 Dec 28	-548 Jan 8	-530 Jan 19

the "Saros Canon" scheme to distinguish it from the "Early" scheme discussed above – seems to have been formulated on the same basis as that of the Early scheme, i.e., the first eclipse in each group was taken as the first eclipse visible 6n − 1 months after a preceding visible eclipse.

Table 2. (Cont.)

	13	14	15	16	17	18
1	-530 Jun 15	-512 Jun 25	-494 Jul 7	-476 Jul 17	-458 Jul 28	-440 Aug 7
2	-530 Dec 10	**-512 Dec 20**	**-493 Jan 1**	-475 Jan 11	**-457 Jan 22**	**-439 Feb 2**
3	**-529 Jun 4**	**-511 Jun 15**	-493 Jun 26	-475 Jul 6	**-457 Jul 17**	-439 Jul 28
4	**-529 Nov 29**	**-511 Dec 10**	-493 Dec 21	**-475 Dec 31**	**-456 Jan 12**	-438 Jan 22
5	-528 May 24	-510 Jun 4	**-492 Jun 14**	**-474 Jun 26**	-456 Jul 6	**-438 Jul 17**
6	**-528 Nov 17**	**-510 Nov 29**	-492 Dec 9	**-474 Dec 20**	**-456 Dec 31**	-437 Jan 11
7	**-527 May 14**	-509 May 25	-491 Jun 4	**-473 Jun 15**	-455 Jun 26	-437 Jul 7
8	-527 Nov 6	-509 Nov 18	-491 Nov 28	-473 Dec 9	-455 Dec 20	-437 Dec 31
9	*-526 Apr 4*	-508 Apr 14	**-490 Apr 25**	-472 May 6	-454 May 17	-436 May 27
10	-526 Sep 27	**-508 Oct 7**	**-490 Oct 19**	-472 Oct 29	**-454 Nov 9**	**-436 Nov 20**
11	-525 Mar 24	**-507 Apr 3**	**-489 Apr 15**	-471 Apr 25	**-453 May 6**	**-435 May 17**
12	**-525 Sep 17**	-507 Sep 27	**-489 Oct 8**	**-471 Oct 19**	-453 Oct 30	**-435 Nov 9**
13	**-524 Mar 12**	**-506 Mar 24**	**-488 Apr 3**	-470 Apr 14	**-452 Apr 24**	**-434 May 6**
14	-524 Sep 5	**-506 Sep 17**	-488 Sep 27	**-470 Oct 8**	**-452 Oct 19**	-434 Oct 30
15	-523 Mar 1	-505 Mar 13	-487 Mar 23	-469 Apr 3	-451 Apr 13	-433 Apr 25
16	-523 Jul 27	-505 Aug 8	-487 Aug 18	-469 Aug 29	-451 Sep 9	-433 Sep 20
17	-522 Jan 20	**-504 Jan 31**	**-486 Feb 11**	-468 Feb 22	**-450 Mar 4**	**-432 Mar 15**
18	**-522 Jul 16**	-504 Jul 27	-486 Aug 7	**-468 Aug 17**	**-450 Aug 29**	-432 Sep 8
19	**-521 Jan 10**	-503 Jan 20	**-485 Jan 31**	**-467 Feb 11**	-449 Feb 22	**-431 Mar 4**
20	**-521 Jul 5**	**-503 Jul 16**	-485 Jul 27	**-467 Aug 6**	**-449 Aug 18**	-431 Aug 28
21	**-521 Dec 30**	**-502 Jan 10**	-484 Jan 21	**-466 Jan 31**	**-448 Feb 12**	-430 Feb 22
22	**-520 Jun 24**	-502 Jul 5	**-484 Jul 15**	**-466 Jul 27**	-448 Aug 6	-430 Aug 17
23	-520 Dec 19	-502 Dec 30	-483 Jan 10	-465 Jan 21	-447 Jan 31	-429 Feb 12
24	-519 May 15	-501 May 26	-483 Jun 5	-465 Jun 17	-447 Jun 27	-429 Jul 8
25	-519 Nov 8	**-501 Nov 19**	-483 Nov 30	**-465 Dec 11**	**-447 Dec 22**	-428 Jan 2
26	**-518 May 5**	-500 May 15	-482 May 26	**-464 Jun 5**	-446 Jun 17	-428 Jun 27
27	-518 Oct 28	**-500 Nov 7**	**-482 Nov 19**	**-464 Nov 29**	**-446 Dec 11**	-428 Dec 21
28	-517 Apr 24	**-499 May 4**	-481 May 16	-463 May 26	**-445 Jun 6**	**-427 Jun 17**
29	**-517 Oct 17**	**-499 Oct 28**	-481 Nov 8	**-463 Nov 18**	**-445 Nov 30**	**-427 Dec 10**
30	-516 Apr 13	-498 Apr 24	-480 May 4	-462 May 15	**-444 May 26**	-426 Jun 6
31	-516 Sep 7	-498 Sep 18	-480 Sep 28	-462 Oct 10	-444 Oct 20	-426 Oct 31
32	-515 Mar 3	**-497 Mar 14**	**-479 Mar 25**	-461 Apr 5	-443 Apr 15	-425 Apr 26
33	-515 Aug 27	**-497 Sep 8**	-479 Sep 18	**-461 Sep 29**	**-443 Oct 10**	-425 Oct 21
34	-514 Feb 20	**-496 Mar 2**	**-478 Mar 14**	-460 Mar 24	**-442 Apr 4**	**-424 Apr 15**
35	**-514 Aug 17**	-496 Aug 27	**-478 Sep 7**	**-460 Sep 18**	-442 Sep 29	**-424 Oct 9**
36	**-513 Feb 9**	**-495 Feb 20**	-477 Mar 3	**-459 Mar 13**	**-441 Mar 25**	-423 Apr 4
37	-513 Aug 8	**-495 Aug 16**	**-477 Aug 28**	-459 Sep 7	-441 Sep 18	**-423 Sep 28**
38	-512 Jan 30	-494 Feb 9	-476 Feb 21	-458 Mar 3	-440 Mar 13	-422 Mar 25

Since the Saros Canon probably covered the period from −526 to −256, Britton suggested that there must have been a reform of the Saros in or around −526.[46] How-

[46] J. P. Britton, "Scientific Astronomy in Pre-Seleucid Babylon," in H. D. Galter (ed.), *Die Rolle der Astronomie in den Kulturen Mesopotamiens* (Grazer Morgenländische Studien, Graz, 1993), 61–76.

Table 2. (Cont.)

	19	20	21	22	23	24
1	*-422 Aug 19*	-404 Aug 29	-386 Sep 9	-368 Sep 20	-350 Oct 1	-332 Oct 11
2	-421 Feb 13	**-403 Feb 23**	**-385 Mar 7**	-367 Mar 17	**-349 Mar 28**	-331 Apr 8
3	-421 Aug 8	**-403 Aug 18**	-385 Aug 30	-367 Sep 9	-349 Sep 20	-331 Oct 1
4	**-420 Feb 2**	**-402 Feb 13**	-384 Feb 24	**-366 Mar 6**	**-348 Mar 17**	-330 Mar 28
5	**-420 Jul 28**	-402 Aug 8	**-384 Aug 18**	**-366 Aug 30**	-348 Sep 9	**-330 Sep 20**
6	**-419 Jan 21**	**-401 Feb 2**	-383 Feb 12	**-365 Feb 23**	**-347 Mar 6**	-329 Mar 17
7	**-419 Jul 17**	**-401 Jul 29**	-383 Aug 8	**-365 Aug 19**	**-347 Aug 30**	-329 Sep 10
8	-418 Jan 10	-400 Jan 22	-382 Feb 1	-364 Feb 12	-346 Feb 23	-328 Mar 5
9	-418 Jun 8	-400 Jun 18	-382 Jun 29	-364 Jul 9	-346 Jul 21	-328 Jul 31
10	-418 Dec 1	**-400 Dec 11**	-382 Dec 23	**-363 Jan 2**	**-345 Jan 14**	-327 Jan 24
11	-417 May 28	-399 Jun 7	**-381 Jun 18**	**-363 Jun 29**	-345 Jul 10	-327 Jul 20
12	**-417 Nov 21**	-399 Dec 1	**-381 Dec 12**	**-363 Dec 23**	**-344 Jan 3**	**-326 Jan 14**
13	-416 May 16	-398 May 27	**-380 Jun 6**	**-362 Jun 18**	-344 Jun 28	**-326 Jul 9**
14	**-416 Nov 9**	**-398 Nov 21**	-380 Dec 1	**-362 Dec 12**	**-344 Dec 23**	**-325 Jan 3**
15	-415 May 5	**-397 May 16**	**-379 May 17**	-361 Jun 7	-343 Jun 17	**-325 Jun 28**
16	-415 Sep 30	-397 Oct 12	-379 Oct 22	-361 Nov 2	-343 Nov 13	-325 Nov 24
17	-414 Mar 26	**-396 Apr 5**	-378 Apr 17	-360 Apr 27	-342 May 8	-324 May 19
18	-414 Sep 19	-396 Sep 30	-378 Oct 11	-360 Oct 21	-342 Nov 2	-324 Nov 12
19	**-413 Mar 16**	-395 Mar 26	**-377 Apr 6**	**-359 Apr 17**	-341 Apr 28	**-323 May 8**
20	**-413 Sep 8**	**-395 Sep 19**	-377 Sep 30	**-359 Oct 10**	**-341 Oct 22**	-323 Nov 1
21	**-412 Mar 4**	**-394 Mar 16**	-376 Mar 26	**-358 Apr 6**	**-340 Apr 17**	-322 Apr 28
22	**-412 Aug 28**	-394 Sep 8	-376 Sep 18	**-358 Sep 30**	-340 Oct 10	**-322 Oct 21**
23	-411 Feb 22	-393 Mar 5	-375 Mar 15	-357 Mar 27	-339 Apr 6	-321 Apr 17
24	-411 Jul 19	-393 Jul 30	-375 Aug 9	-357 Aug 21	-339 Aug 31*	-321 Sep 11*
25	-410 Jan 12	**-392 Jan 23**	-374 Feb 3	-356 Feb 14	-338 Feb 24	-320 Mar 7
26	**-410 Jul 8**	**-392 Jul 19**	-374 Jul 30	**-356 Aug 9**	**-338 Aug 21**	-320 Aug 31
27	**-409 Jan 1**	**-391 Jan 12**	-373 Jan 23	**-355 Feb 2**	**-337 Feb 14**	-319 Feb 24
28	-409 Jun 28	**-391 Jul 8**	**-373 Jul 20**	-355 Jul 30	-337 Aug 10	**-319 Aug 20**
29	**-409 Dec 22**	-390 Jan 1	**-372 Jan 12**	**-354 Jan 23**	-336 Feb 3	**-318 Feb 13**
30	**-408 Jun 16**	**-390 Jun 28**	-372 Jul 8	-354 Jul 19	**-336 Jul 29**	**-318 Aug 10**
31	-408 Nov 11	-390 Nov 22	-372 Dec 2	-354 Dec 14	-336 Dec 24	-317 Jan 5
32	-407 May 7	-389 May 18	-371 May 28	-353 Jun 9	-335 Jun 19	-317 Jun 30
33	**-407 Oct 31**	**-389 Nov 12**	-371 Nov 22	**-353 Dec 3**	**-335 Dec 14**	-317 Dec 25
34	-406 Apr 26	-388 May 6	**-370 May 17**	-352 May 28	-334 Jun 8	**-316 Jun 18**
35	**-406 Oct 21**	-388 Oct 31	**-370 Nov 11**	**-352 Nov 22**	-334 Dec 3	**-316 Dec 13**
36	**-405 Apr 15**	**-387 Apr 26**	-369 May 7	**-351 May 17**	**-333 May 29**	-315 Jun 8
37	**-405 Oct 10**	-387 Oct 20	**-369 Oct 31**	**-351 Nov 11**	-333 Nov 22	**-315 Dec 2**
38	-404 Apr 4	**-386 Apr 15**	**-368 Apr 26**	-350 May 7	**-332 May 17**	**-314 May 29**

ever, it is clear from Tables 2 and 3 that this cannot have been the case. A number of eclipses were predicted and recorded by the Babylonian astronomers between −526 and −256 that are not considered eclipse possibilities on the Saros Canon. It should be noted that the records which do not correspond to the Saros Canon scheme are not all taken from the preserved parts of the large compilation – which may have indicated that they were simply filling in the rows in the text and were not actual predictions made

Table 2. (Cont.)

	25	26	27	28	29	30
				-260 Dec 23	-241 Jan 4	-223 Jan 14
1	-314 Oct 23	-296 Nov 2	-278 Nov 13			
2	-313 Apr 19	-295 Apr 29	-277 May 11	-259 May 21	-241 Jun 1	-223 Jun 11
3	-313 Oct 12	-295 Oct 22	-277 Nov 3	-259 Nov 13	-241 Nov 25	-223 Dec 5
4	**-312 Apr 7**	**-294 Apr 18**	**-276 Apr 29**	-258 May 10	**-240 May 20**	**-222 Jun 1**
5	**-312 Oct 1**	-294 Oct 12	**-276 Oct 22**	-258 Nov 3	**-240 Nov 13**	**-222 Nov 25**
6	**-311 Mar 27**	**-293 Apr 8**	**-275 Apr 18**	-257 Apr 29	**-239 May 9**	**-221 May 21**
7	**-311 Sep 20**	**-293 Oct 2**	-275 Oct 12	**-257 Oct 23**	-239 Nov 3	**-221 Nov 14**
8	-310 Mar 16	**-292 Mar 27**	-274 Apr 7	-256 Apr 17	**-238 Apr 28**	-220 May 9
				-256 Oct 12	**-238 Oct 23**	-220 Nov 3
9	-310 Aug 11	-292 Aug 22	-274 Sep 2			
10	**-309 Feb 4**	**-291 Feb 15**	-273 Feb 26	-255 Mar 8	-237 Mar 20	-219 Mar 30
11	-309 Jul 31	-291 Aug 11	-273 Aug 22	-255 Sep 1	-237 Sep 14	-219 Sep 23
12	-308 Jan 25	**-290 Feb 4**	**-272 Feb 16**	-254 Feb 26	**-236 Mar 8**	**-218 Mar 20**
13	**-308 Jul 20**	-290 Jul 31	-272 Aug 10	**-254 Aug 21**	**-236 Sep 1**	-218 Sep 12
14	**-307 Jan 14**	-289 Jan 25	**-271 Feb 4**	**-253 Feb 16**	-235 Feb 26	**-217 Mar 9**
15	**-307 Jul 9**	-289 Jul 20	**-271 Jul 30**	**-253 Aug 11**	-235 Aug 21	**-217 Sep 1**
				-252 Feb 5	-234 Feb 15	-216 Feb 27
16	-307 Dec 4	-289 Dec 16	-271 Dec 26	-252 Jul 30	**-234 Aug 11**	-216 Aug 21
17	-306 May 30	-288 Jun 9	-270 Jun 21			
18	-306 Nov 23	-288 Dec 4	-270 Dec 15	-252 Dec 25	-233 Jan 6	-215 Jan 16
19	**-305 May 20**	-287 May 30	**-269 Jun 10**	**-251 Jun 21**	-233 Jul 2	-215 Jul 12
20	**-305 Nov 12**	**-287 Nov 23**	-269 Dec 4	**-251 Dec 14**	**-233 Dec 26**	-214 Jan 5
21	**-304 May 8**	**-286 May 20**	-268 May 30	-250 Jun 10	**-232 Jun 20**	**-214 Jul 4**
22	**-304 Nov 1**	-286 Nov 12	**-268 Nov 22**	**-250 Dec 4**	-232 Dec 14	**-214 Dec 25**
23	**-303 Apr 28**	-285 May 9	-267 May 19	**-249 May 30**	**-231 Jun 10**	-213 Jun 21
				-249 Nov 23	-231 Dec 4	-213 Dec 15
24	-303 Sep 22	-285 Oct 3*	-267 Oct 13			
25	-302 Mar 18	-284 Mar 28	-266 Apr 9	*-248 Apr 19*	*-230 Apr 30*	-212 May 10
26	-302 Sep 11	-284 Sep 22	-266 Oct 3	-248 Oct 13	-230 Oct 25	-212 Nov 4
27	**-301 Mar 7**	**-283 Mar 17**	**-265 Mar 29**	-247 Apr 8	**-229 Apr 19**	**-211 Apr 30**
28	-301 Sep 1	-283 Sep 11	**-265 Sep 22**	**-247 Oct 3**	-229 Oct 14	**-211 Oct 24**
29	**-300 Feb 25**	-282 Mar 7	**-264 Mar 17**	**-246 Mar 29**	-228 Apr 8	**-210 Apr 19**
30	-300 Aug 20	**-282 Aug 31**	**-264 Sep 11**	-246 Sep 22	**-228 Oct 2**	**-210 Oct 14**
				-245 Mar 18	-227 Mar 29	-209 Apr 9
31	-299 Jan 15	-281 Jan 26*	-263 Feb 6	-245 Sep 11	-227 Sep 21	-209 Oct 3
32	-299 Jul 10	-281 Jul 22	-263 Aug 1			
33	**-298 Jan 4**	-280 Jan 16	-262 Jan 26	**-244 Feb 7**	-226 Feb 17	-208 Feb 28
34	**-298 Jun 30**	-280 Jul 10	-262 Jul 21	-244 Aug 1	-226 Aug 12	-208 Aug 22
35	**-298 Dec 25**	-279 Jan 4	**-261 Jan 15**	**-243 Jan 26**	-225 Feb 6	**-207 Feb 16**
36	**-297 Jun 19**	**-279 Jun 30**	-261 Jul 11	**-243 Jul 21**	**-225 Aug 2**	-207 Aug 12
37	**-297 Dec 14**	-279 Dec 24	**-260 Jan 4**	**-242 Jan 15**	-224 Jan 26	**-206 Feb 5**
38	-296 Jun 8	**-278 Jun 19**	**-260 Jun 30**	-242 Jul 11	**-224 Jul 21**	**-206 Aug 2**

at the time – but also from two other collections: LBAT 1426+1427 and LBAT 1432. The former text is, like the large compilation, arranged in 18-year cycles; however it is unlikely that it would stretch back as far as −526 and would not, therefore, be expected to follow the early scheme if this scheme was not in use after this date. The second text is a collection of lunar eclipses arranged as a simple chronological list. The preserved

Table 2. (Cont.)

	31	32	33	34	35	36
1	-205 Jan 25	-187 Feb 5	-169 Feb 16	-151 Feb 26	-133 Mar 10	-115 Mar 20
2	-205 Jul 22	-187 Aug 1	-169 Aug 13	-151 Aug 23	-133 Sep 3	-115 Sep 14
3	-205 Dec 16	-187 Dec 27	*-168 Jan 7*	-150 Jan 17	*-132 Jan 29*	-114 Feb 8
4	-204 Jun 11	-186 Jun 22	-168 Jul 2	-150 Jul 14	-132 Jul 24	-114 Aug 4
5	-204 Dec 5	**-186 Dec 16**	**-168 Dec 27**	-149 Jan 7	**-131 Jan 17**	**-113 Jan 29**
6	-203 May 31	-185 Jun 11	**-167 Jun 21**	**-149 Jul 3**	-131 Jul 13	**-113 Jul 24**
7	**-203 Nov 25**	-185 Dec 6	**-167 Dec 16**	**-149 Dec 28**	-130 Jan 7	**-112 Jan 18**
8	-202 May 20	**-184 May 30**	**-166 Jun 11**	-148 Jun 21	**-130 Jul 2**	**-112 Jul 13**
9	-202 Nov 14	-184 Nov 24	-166 Dec 6	-148 Dec 16	-130 Dec 27	-111 Jan 7
						-111 Jul 2
10	-201 Apr 10	-183 Apr 21	-165 May 2	-147 May 12	*-129 May 24*	
11	-201 Oct 4	-183 Oct 15	-165 Oct 26	-147 Nov 5	-129 Nov 17	-111 Nov 27
12	-200 Mar 30	**-182 Apr 10**	**-164 Apr 21**	-146 May 2	**-128 May 12**	**-110 May 24**
13	**-200 Sep 22**	**-182 Oct 4**	-164 Oct 14	**-146 Oct 25**	**-128 Nov 5**	-110 Nov 16
14	**-199 Mar 20**	-181 Mar 31	**-163 Apr 10**	**-145 Apr 22**	-127 May 2	-109 May 13
15	**-199 Sep 12**	-181 Sep 23	**-163 Oct 3**	**-145 Oct 15**	-127 Oct 25	**-109 Nov 5**
16	-198 Mar 9	-180 Mar 19	-162 Mar 31	-144 Apr 10	-126 Apr 21	-108 May 1
17	-198 Sep 1	**-180 Sep 12**	-162 Sep23	**-144 Oct 3**	**-126 Oct 15**	-108 Oct 25
18	-197 Jan 27	-179 Feb 7	*-161 Feb 18*	-143 Feb 28	*-125 Mar 11*	-107 Mar 22
19	-197 Jul 24	-179 Aug 3	-161 Aug 14	-143 Aug 25	-125 Sep 5	-107 Sep 15
20	**-196 Jan 16**	**-178 Jan 27**	-160 Feb 7	**-142 Feb 17**	**-124 Feb 29**	-106 Mar 11
21	-196 Jul 12	**-178 Jul 23**	**-160 Aug 3**	-142 Aug 14	**-124 Aug 24**	**-106 Sep 5**
22	**-195 Jan 5**	-177 Jan 16	**-159 Jan 26**	**-141 Feb 7**	-123 Feb 17	**-105 Feb 28**
23	**-195 Jul 1**	**-177 Jul 12**	-159 Jul 23	-141 Aug 3	**-123 Aug 13**	**-105 Aug 25**
24	-195 Dec 25	-176 Jan 6	-158 Jan 16	-140 Jan 27	-122 Feb 7	-104 Feb 18
25	-194 Jun 20	-176 Jul 1	-158 Jul 12	-140 Jul 22	**-122 Aug 2**	-104 Aug 13
26	*-194 Nov 15*	-176 Nov 26	*-158 Dec 7*	-140 Dec 18	*-122 Dec 29*	-103 Jan 8
27	-193 May 11	**-175 May 21**	**-157 Jun 2**	-139 Jun 12	-121 Jun 23	-103 Jul 3
28	**-193 Nov 5**	**-175 Nov 15**	**-157 Nov 26**	-139 Dec 7	**-121 Dec 18**	**-103 Dec 29**
29	**-192 Apr 30**	-174 May 11	-156 May 21	**-138 Jun 2**	**-120 Jun 12**	-102 Jun 23
30	-192 Oct 24	**-174 Nov 4**	**-156 Nov 15**	**-138 Nov 26**	-120 Dec 6	**-102 Dec 18**
31	-191 Apr 19	-173 May1	-155 May 11	-137 May 22	-119 Jun 2	-101 Jun 13
32	-191 Oct 13	-173 Oct 24	-155 Nov 4	-137 Nov 15	-119 Nov 15	-101 Dec 7
						-100 Jun 1
33	*-190 Mar 10*	*-172 Mar 21*	-154 Apr 1	-136 Apr 11	-118 Apr 23	
34	-190 Sep 3	-172 Sep 13	-154 Sep 24	-136 Oct 5	-118 Oct 16	-100 Oct 26
35	**-189 Feb 28**	-171 Mar 10	**-153 Mar 21**	**-135 Apr 1**	-117 Apr 12	-99 Apr 22
36	**-189 Aug 23**	**-171 Sep 3**	-153 Sep 14	**-135 Sep 24**	**-117 Oct 6**	-99 Oct 16
37	**-188 Feb 17**	-170 Feb 27	**-152 Mar 9**	**-134 Mar 21**	-116 Mar 31	**-98 Apr 11**
38	-188 Aug 12	**-170 Aug 23**	**-152 Sep 3**	-134 Sep 14	**-116 Sep 24**	**-98 Oct 6**

part covers the period from −279 to −277, and it would seem likely that the collection was made only shortly after this time. It would therefore be very strange if it did not contain the eclipse observations and predictions taken directly from the Diaries, and so the eclipse predictions in this text must represent the scheme being used at that time.

Table 2. (Cont.)

	37	38	39	40	41	42
1	**-97 Mar 31**	**-79 Apr 11**	-61 Apr 22	**-43 May 2**	**-25 May 14**	-7 May 24
2	-97 Sep 25	**-79 Oct 5**	**-61 Oct 17**	-43 Oct 27	**-25 Nov 7**	**-7 Nov 18**
3	-96 Feb 19	-78 Mar 2	-60 Mar 12	-42 Mar 23	-24 Apr 3	*-6 Apr 14*
4	-96 Aug 14	-78 Aug 26	-60 Sep 5	-42 Sep 16	-24 Sep 27	-6 Oct 8
5	-95 Feb 8	**-77 Feb 19**	-59 Mar 2	-41 Mar 13	**-23 Mar 23**	-5 Apr 4
6	**-95 Aug 4**	-77 Aug 15	-59 Aug 25	**-41 Sep 5**	**-23 Sep 16**	-5 Sep 27
7	**-94 Jan 29**	-76 Feb 9	**-58 Feb 19**	**-40 Mar 2**	-22 Mar 13	**-4 Mar 23**
8	-94 Jul 24	-76 Aug 3	**-58 Aug 14**	**-40 Aug 25**	-22 Sep 5	**-4 Sep 15**
9	-93 Jan 18	**-75 Jan 28**	**-57 Feb 9**	-39 Feb 19	**-21 Mar 2**	-3 Mar 13
10	**-93 Jul 13**	-75 Jul 24	-57 Aug 2	**-39 Aug 14**	**-21 Aug 26**	-3 Sep 5
11	-93 Dec 8	*-75 Dec 19*	-57 Dec 30	-38 Jan 9	-20 Jan 21	-2 Jan 27
12	-92 Jun 3	-74 Jun 14	-56 Jun 24	-38 Jul 6	-20 Jul 16	-2 Jul 27
13	**-92 Nov 26**	**-74 Dec 8**	-56 Dec 18	**-38 Dec 29**	**-19 Jan 9**	-1 Jan 20
14	**-91 May 23**	**-73 Jun 4**	-55 Jun 14	**-37 Jun 25**	**-19 Jul 6**	-1 Jul 17
15	**-91 Nov 16**	-73 Nov 27	**-55 Dec 7**	**-37 Dec 19**	**-19 Dec 29**	**0 Jan 10**
16	**-90 May 13**	-72 May 23	-54 Jun 3	**-36 Jun 13**	**-18 Jun 25**	0 Jul 5
17	**-90 Nov 5**	**-72 Nov 16**	-54 Nov 27	**-36 Dec 7**	-18 Dec 19	**0 Dec 29**
18	-89 Apr 2	-71 Apr 12	-53 Apr 24	-35 May 4	-17 May 15	+1 May 25
19	-89 Sep 27	-71 Oct 7	-53 Oct 18	-35 Oct 29	-17 Nov 9	+1 Nov 19
20	**-88 Mar 21**	**-70 Apr 2**	-52 Apr 12	-34 Apr 23	**-16 May 4**	+2 May 15
21	-88 Sep 15	**-70 Sep 26**	**-52 Oct 7**	-34 Oct 18	**-16 Oct 28**	**+2 Nov 9**
22	**-87 Mar 11**	-69 Mar 22	**-51 Apr 1**	**-33 Apr 13**	-15 Apr 23	**+3 May 4**
23	-87 Sep 4	**-69 Sep 15**	**-51 Sep 26**	-33 Oct 7	**-15 Oct 15**	**+3 Oct 29**
24	**-86 Mar 1**	-68 Mar 11	-50 Mar 26	**-32 Apr 2**	-14 Apr 13	+4 Apr 23
25	-86 Aug 24	**-68 Sep 3**	**-50 Sep 15**	-32 Sep 25	**-14 Oct 6**	**+4 Oct 17**
26	-85 Jan 20	-67 Jan 30	-49 Feb 10	-31 Feb 21	-13 Mar 4	+5 Mar 14
27	-85 Jul 15	-67 Jul 25	-49 Aug 5	-31 Aug 16	-13 Aug 27	+5 Sep 6
28	-84 Jan 9	**-66 Jan 19**	**-48 Jan 31**	-30 Feb 10	-12 Feb 21	**+6 Mar 3**
29	**-84 Jul 3**	-66 Jul 15	-48 Jul 25	**-30 Aug 5**	**-12 Aug 16**	+6 Aug 27
30	**-84 Dec 28**	**-65 Jan 8**	**-47 Jan 19**	**-29 Jan 30**	-11 Feb 9	**+7 Feb 20**
31	-83 Jun 23	**-65 Jul 4**	-47 Jul 15	-29 Jul 26	**-11 Aug 5**	**+7 Aug 17**
32	-83 Dec 17	**-65 Dec 28**	**-46 Jan 8**	-28 Jan 19	**-10 Jan 29**	**+8 Feb 10**
33	-82 Jun 13	-64 Jun 23	-46 Jul 4	-28 Jul 15	-10 Jul 26	+8 Aug 5
34	-82 Nov 7	-64 Nov 17	-46 Nov 28	-28 Dec 9	-10 Dec 20	+8 Dec 31
35	**-81 May 3**	**-63 May 14**	-45 May 25	-27 Jun 4	-9 Jun 16	+9 Jun 26
36	**-81 Oct 27**	-63 Nov 7	-45 Nov 18	**-27 Nov 28**	**-9 Dec 10**	**+9 Dec 20**
37	**-80 Apr 21**	**-62 May 3**	-44 May 13	**-26 May 24**	**-8 Jun 4**	+10 Jun 15
38	-80 Oct 16	**-62 Oct 27**	**-44 Nov 7**	-26 Nov 18	**-8 Nov 28**	**+10 Dec 10**

This all points to the conclusion that the Early scheme was the basis by which lunar eclipse predictions were made for the Diaries down to about −250. Additional evidence for this is given by a number of Diary predictions which are part of Saros series that either do not stem from an eclipse that has been visible, or from one where the last visible eclipse was some considerable time earlier. For example, a record of an eclipse

Table 3. Dates of eclipse predictions given by the Early Saros Scheme and the Saros Canon Scheme over an eighteen year period. Underlined dates relate to preserved records. Two recorded eclipses (−422 Aug 19 and −408 Nov 11) predicted by the old scheme are not considered eclipse possibilities in the Saros Canon Scheme

Early Scheme	Saros Canon Scheme
−422 Aug 19 (5 months)	−422 Jul 20
−421 Feb 13	−421 Feb 13 (5 months)
−421 Aug 8	−421 Aug 8
−420 Feb 2	−420 Feb 2
−420 Jul 28	−420 Jul 28
−419 Jan 21	−419 Jan 21
−419 Jul 17	−419 Jul 17
−418 Jan 10	−418 Jan 10
−418 Jun 8 (5 months)	−418 Jun 8 (5 months)
−418 Dec 1	−418 Dec 1
−417 May 28	−417 May 28
−417 Nov 21	−417 Nov 21
−416 May 16	−416 May 16
−416 Nov 9	−416 Nov 9
−415 May 5	−415 May 5
−415 Sep 20 (5 months)	−415 Oct 30
−414 Mar 26	−414 Mar 26 (5 months)
−414 Sep 19	−414 Sep 19
−413 Mar 16	−413 Mar 16
−413 Sep 8	−413 Sep 8
−412 Mar 4	−412 Mar 4
−412 Aug 28	−412 Aug 28
−411 Feb 22	−411 Feb 22
−411 Jul 19 (5 months)	−411 Aug 17
−410 Jan 12	−410 Jan 12 (5 months)
−410 Jul 8	−410 Jul 8
−409 Jan 1	−409 Jan 1
−409 Jun 28	−409 Jun 28
−409 Dec 22	−409 Dec 22
−408 Jun 16	−408 Jun 16
−408 Nov 11 (5 months)	−408 Dec 10
−407 May 7	−407 May 7 (5 months)
−407 Oct 31	−407 Oct 31
−406 Apr 26	−406 Apr 26
−406 Oct 21	−406 Oct 21
−405 Apr 15	−405 Apr 15
−405 Oct 10	−405 Oct 10
−404 Apr 4	−404 Apr 4

prediction for −567 July 4 is preserved on the Diary fragment VAT 4946. There had been no visible eclipse in this Saros series before this date. Another example is found in the Diary LBAT 166. Here, an eclipse is predicted for −382 June 29, some 6 cycles after the previously visible eclipse in its Saros series. Furthermore, this eclipse is at an interval of 23 months from the last visible eclipse, and so it is hard to see how it could have been predicted without the use of a scheme such as the Early Saros. There are a number of other example of eclipse predictions which it seems unlikely that they would have been made without the use of the Early Saros scheme.

Given that the Saros Canon scheme does not appear to have been the means by which the eclipse predictions for the Diaries were made, we may then wonder about the purpose of the texts on which it is presented. I can think of two possibilities, both of which are related. First, they may record the results of an attempt to derive the layout of the eclipse possibilities within a Saros theoretically, following a procedure similar to that used by Aaboe. The second possibility, which I find more likely, is that the Saros Canon scheme was one of a number of schemes that were formulated empirically towards the end of the fourth century BC when the Early scheme was beginning to fail. We might even wonder if texts containing other variant schemes for this period will one day surface.[47]

Sometime between −278 and −248 the Saros *was* revised (in other words, the date of the first eclipse in the 8-7-8-7-8 layout has been changed), but to a different scheme again from that found on the Saros Canon. This is shown by the eclipse prediction on −248 April 19, which is stated to be at a five month interval. Whilst this eclipse would have been predicted by the Early scheme, it would have been six months after the previous eclipse possibility rather than five months. Furthermore, an eclipse predicted for −245 September 11 would not have been predicted by the Early scheme. I have illustrated the revision by a vertical line between columns 27 and 28 in the table. The exact date of the revision, however, is not known; all that may be said is that it took place sometime after the −278 November 13 and before the −248 April 19 prediction.

It would appear from Table 2 that there were two more revisions of the Saros: one around −200 and the other around −110. The layout of the eclipse possibilities within the Saros cycle after −200 is clearly shown by the many reports of predictions noting the five month interval. However, the layout of the −110 revision is still somewhat tentative, in particular in the placing of the five month interval between rows 17 and 18. This interval may have been one eclipse possibility later. The motivation for this latter revision is not entirely clear. The previous scheme had correctly predicted all of the eclipses visible at Babylon over the period it had been in use.

Solar eclipses appear to have been treated in exactly the same fashion as lunar eclipses by the Babylonian astronomers, despite the fact there are far fewer solar than lunar eclipses visible form any given site over a particular time interval. Due to the vagaries of preservation, before the Seleucid period far fewer records of eclipses of the sun are preserved in the NMAT texts than is the case for the moon. Indeed, only one text, the so called "Text S", contains reports of solar eclipses from before −381.[48] This text,

[47] Perhaps the theoretical Text L which has an unusual distribution into 8-7-7-8-8 groups may fall into this category. On this text, see 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), 35–62.

[48] First published as Texts B, C, and D by A. Aaboe and A. J. Sachs, "Two Lunar Texts of the Achaemenid Period from Babylon," *Centaurus* 14 (1969), 1–22, and republished with an additional fragment as Text S by J. P. Britton, "An Early Function for Eclipse Magnitude in Babylonian Astronomy," *Centaurus* 32 (1989), 1–52. In addition, a tablet from Nippur, CBS 11901, contains a prediction of a solar eclipse on −424 October 23. This tablet was last discussed in its

which is unique in Babylonian astronomy in containing both functions of mathematical astronomy and observational remarks presumably taken from the Diaries, is problematic in that it gives contradictory dates for one of the eclipse predictions. I shall adopt the dates given as part of the observational comments. We can then proceed to reconstruct the distribution of eclipses within the Saros in exactly the same fashion as for the lunar eclipses. This is shown in Table 4 which has the same form as Table 2.

Clearly the first 12 cycles in the table are not very well defined. Those from 6 to 12 are somewhat arbitrarily based upon the "Solar Saros," a theoretical text similar to the Saros Canon, since there are insufficient records to propose any other layout.[49] This leads to a revision of the Saros between those predictions reported in Text S and those in the other NMAT sources from −381 and after. However, due to the problematic nature of Text S, I do not believe we can be certain that this revision indeed took place (the earlier layout should perhaps be the same as that after −381), or indeed that the layout presented here for columns 6 to 12 (which is based upon the Solar Saros) was in fact the one used. It is certain, however, that around −250 there was a revision of the Saros and after this time the layout of the table is not in any doubt. Three more revisions were made in about −200, −110 and −65. Interestingly, the −250, −200 and −110 dates are similar to those in which there was a revision of the lunar Saros, and it seems quite possible that both were revised together. Unfortunately, there are so few records of lunar eclipses from after about −60 that our knowledge of the lunar Saros is limited at this period, but it is possible that this may also have been revised around this date. This is as we would expect if, as seems to be the case, lunar and solar eclipses were treated in the same way by the Babylonian astronomers. Since solar eclipses can occur at greater nodal elongations than lunar eclipses, it was necessary to revise the solar Saros scheme more often than the lunar Saros. If the lunar Saros was always revised at the same time as the solar this would explain the reform in about −110 which otherwise seemed to be unnecessary. There is in fact an even closer link between the lunar and solar Saroi, at least in the period after −250. From here until at least −70, it would seem that the solar and lunar Saroi have the same 8-7-8-7-8 distribution, with the solar Saros always starting 4 eclipse possibilities earlier than the lunar Saros.[50]

We may also wonder about the role of mathematical astronomy in the prediction of these eclipses. It is well known that by the Seleucid era the Babylonians were in possession of two highly developed lunar theories which could be used to predict eclipses. Could these have been used to make the predictions in the later NMAT texts, and are the revisions I have so far identified simply manifestations of the use of these theories?

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entirety by F. X. Kugler, *Sternkunde und Sterdienst in Babel. Ergänzungen II* (Aschendorffsche Verlagsbuchhandlung, Münster, 1914), 233–234.

[49] I have here accepted the corrections to the Solar Saros proposed 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). Uncorrected, the Solar Saros contains not the expected 8-7-8-7-8 distribution of eclipses, but an 8-8-6-8-8 distribution. It should be noted that any correction applied is in some ways arbitrary.

[50] This effectively confirms the placing of the five month interval between rows 17 and 18 in the final part of the lunar Saros table.

Table 4. Distribution of solar eclipse possibilites over the Late Babylonian period

	1	2	3	4	5	6
1	*-474 Dec 5*	**-456 Dec 16**	-438 Dec 27	-419 Jan 7	**-401 Jan 18**	-383 Jan 28
2	-473 May 31	-455 Jun 11	-437 Jun 22	-419 Jul 2	-401 Jul 14	-383 Jul 24
3	-473 Nov 25	-455 Dec 5	**-437 Dec 17**	-419 Dec 27	-400 Jan 8	-382 Jan 18
4	-472 May 20	**-454 May 31**	**-436 Jun 10**	-418 Jun 22	-400 Jul 2	**-382 Jul 13**
5	-472 Nov 13	-454 Nov 25	-436 Dec 5	-418 Dec 17	-400 Dec 27	-381 Jan 7
6	-471 May 9	-453 May 20	**-435 May 31**	-417 Jun 11	-399 Jun 21	-381 Jul 3
7	-471 Nov 3	-453 Nov 14	-435 Nov 24	-417 Dec 6	-399 Dec 16	-381 Dec 27
8	-470 Apr 29	-452 May 9	-434 May 20	-416 May 31	-398 Jun 11	
						-380 May 23
9	*-470 Sep 23*	-452 Oct 3	-434 Oct 15	-416 Oct 25	-398 Nov 5	-380 Nov 16
10	**-469 Mar 20**	-451 Mar 30	-433 Apr 11	**-415 Apr 21**	-397 May 2	-379 May 13
11	-469 Sep 12	-451 Sep 23	**-433 Oct 4**	-415 Oct 14	-397 Oct 26	**-379 Nov 5**
12	-468 Mar 8	**-450 Mar 20**	**-432 Mar 30**	-414 Apr 10	-396 Apr 21	**-378 May 2**
13	-468 Sep 1	-450 Sep 12	-432 Sep 22	**-414 Oct 4**	-396 Oct 14	-378 Oct 26
14	-467 Feb 25	**-449 Mar 9**	-431 Mar 19	-413 Mar 30	-395 Apr 10	-377 Apr 21
15	-467 Aug 21	-449 Sep 2	-431 Sep 12	-413 Sep 24	-395 Oct 4	-377 Oct 15
16	-466 Jan 16	-448 Jan 27	-430 Feb 7	-412 Feb 18	-394 Feb 28	-376 Mar 11
17	-466 Jul 23	-448 Jul 23	**-430 Aug 3**	-412 Aug 14	-394 Aug 25	**-376 Sep 4**
18	-465 Jan 5	-447 Jan 16	-429 Jan 27	-411 Feb 6	-393 Feb 18	-375 Feb 28
19	**-465 Jul 2**	**-447 Jul 12**	-429 Jul 23	-411 Aug 3	**-393 Aug 14**	-375 Aug 24
20	**-465 Dec 26**	-446 Jan 5	-428 Jan 17	-410 Jan 27	-392 Feb 7	-374 Feb 18
21	-464 Jun 20	-446 Jul 1	-428 Jul 11	-410 Jul 23	-392 Aug 2	-374 Aug 13
22	-464 Dec 14	**-446 Dec 26**	-427 Jan 5	-409 Jan 17	**-391 Jan 27**	-373 Feb 7
23	-463 Jun 9	-445 Jun 20	-427 Jul 1	-409 Jul 12	-391 Jul 22	
						-373 Jul 4
24	-463 Nov 4	-445 Nov 16	-427 Nov 26	-409 Dec 7	-391 Dec 18	-373 Dec 29
25	**-462 Apr 30**	-444 May 10	**-426 May 22**	**-408 Jun 1**	-390 Jun 12	-372 Jun 23
26	-462 Oct 24	-444 Nov 4	-426 Nov 15	-408 Nov 25	-390 Dec 7	-372 Dec 17
27	-461 Apr 20	-443 Apr 30	-425 May 11	-407 May 22	**-389 Jun 2**	-371 Jun 12
28	-461 Oct 13	-443 Oct 24	**-425 Nov 4**	-407 Nov 14	-389 Nov 26	**-371 Dec 6**
29	-460 Apr 8	-442 Apr 20	-424 Apr 30	-406 May 11	-388 May 22	-370 Jun 2
30	-460 Oct 2	-442 Oct 13	-424 Oct 23	-406 Nov 4	**-388 Nov 14**	-370 Nov 25
31	*-459 Feb 27*	-441 Mar 11	**-423 Mar 21**	-405 Apr 1	-387 Apr 12	**-369 Apr 23**
32	-459 Aug 23	-441 Sep 3	-423 Sep 13	-405 Sep 25	-387 Oct 5	-369 Oct 17
33	-458 Feb 16	-440 Feb 28	**-422 Mar 10**	-404 Mar 20	-386 Apr 1	**-368 Apr 11**
34	-458 Aug 12	**-440 Aug 23**	-422 Sep 3	-404 Sep 13	**-386 Sep 25**	-368 Oct 5
35	-457 Feb 5	-439 Feb 16	-421 Feb 27	-403 Mar 9	-385 Mar 21	-367 Mar 31
36	**-457 Aug 2**	-439 Aug 12	-421 Aug 24	**-403 Sep 3**	-385 Sep 14	-367 Sep 25
37	-456 Jan 26	-438 Feb 5	-420 Feb 16	-402 Feb 27	-384 Mar 9	-366 Mar 20
38	-456 Jul 21	-438 Aug 2	-420 Aug 12	**-402 Aug 23**	-384 Sep 3	-366 Sep 14

Before we can consider this problem it will be necessary to briefly outline the way in which one uses Systems A and B to predict eclipses.[51]

[51] For a detailed discussion of these methods, see O. Neugebauer, *Astronomical Cuneiform Texts* (Lund Humphries, London, 1955), 41–85 and "Studies in Ancient Astronomy VII: Magni-

Table 4. (Cont.)

	7	8	9	10	11	12
1	-365 Feb 9	**-347 Feb 19**	-329 Mar 2	-311 Mar 13	-293 Mar 24	-275 Apr 3
2	-365 Aug 4	-347 Aug 14	-329 Aug 26	-311 Sep 5	-293 Sep 16	-275 Sep 27
3	-364 Jan 29	-346 Feb 9	**-328 Feb 20**	-310 Mar 2	-292 Mar 13	**-274 Mar 24**
4	-364 Jul 23	-346 Aug 4	-328 Aug 14	-310 Aug 25	-292 Sep 5	-274 Sep 16
5	-363 Jan 18	-345 Jan 29	-327 Feb 8	-309 Feb 20	-291 Mar 2	-273 Mar 13
6	**-363 Jul 13**	-345 Jul 24	-327 Aug 4	**-309 Aug 15**	-291 Aug 25	-273 Sep 6
7	-362 Jan 7	-344 Jan 18	-326 Jan 28	-308 Feb 9	-290 Feb 19	-272 Mar 1
8	-362 Jun 3	-344 Jun 14	-326 Jun 25	-308 Jul 5	-290 Jul 17	-272 Jul 27
9	**-362 Nov 27**	-344 Dec 7	-326 Dec 19	**-308 Dec 29**	-289 Jan 9	-271 Jan 20
10	-361 May 24	-343 Jun 3	-325 Jun 15	-307 Jun 25	-289 Jul 6	-271 Jul 16
11	-361 Nov 16	-343 Nov 27	**-325 Dec 8**	-307 Dec 18	-289 Dec 30	**-270 Jan 9**
12	**-360 May 12**	-342 May 24	-324 Jun 3	**-306 Jun 14**	-288 Jun 24	-270 Jul 6
13	-360 Nov 5	-342 Nov 16	-324 Nov 27	-306 Dec 8	-288 Dec 18	-270 Dec 30
14	-359 May 1	-341 May 13	**-323 May 23**	-305 Jun 3	-287 Jun 13	-269 Jun 25
15	-359 Oct 26	-341 Nov 6	-323 Nov 16	-305 Nov 28	-287 Dec 8	-269 Dec 19
16	-358 Mar 22	-340 Apr 1	-322 Apr 12	-304 Apr 23	-286 May 4	-268 May 14
17	-358 Sep 15	-340 Sep 26	**-322 Oct 7**	-304 Oct 17	-286 Oct 29	**-268 Nov 8**
18	-357 Mar 11	-339 Mar 22	-321 Apr 2	-303 Apr 12	-285 Apr 24	-267 May 4
19	-357 Sep 5	**-339 Sep 15**	**-321 Sep 26**	-303 Oct 7	**-285 Oct 18**	**-267 Oct 28**
20	**-356 Feb 29**	-338 Mar 11	-320 Mar 22	**-302 Apr 2**	-284 Apr 12	-266 Apr 24
21	-356 Aug 24	**-338 Sep 4**	-320 Sep 14	-302 Sep 26	**-284 Oct 6**	-266 Oct 17
22	-355 Feb 18	-337 Mar 1	-319 Mar 11	-301 Mar 23	-283 Apr 2	-265 Apr 13
23	*-355 Jul 14*	*-337 Jul 26*	*-319 Aug 5*	-301 Aug 16	-283 Aug 27	-265 Sep 7
24	-354 Jan 8	-336 Jan 20	-318 Jan 30	-300 Feb 10	-282 Feb 21	-264 Mar 3
25	-354 Jul 4	-336 Jul 14	-318 Jul 26	-300 Aug 5	-282 Aug 16	-264 Aug 27
26	-354 Dec 28	-335 Jan 8	-317 Jan 19	-299 Jan 29	-281 Feb 10	-263 Feb 20
27	-353 Jun 24	**-335 Jul 4**	-317 Jul 15	-299 Jul 26	**-281 Aug 6**	-263 Aug 16
28	-353 Dec 18	-335 Dec 28	**-316 Jan 8**	-298 Jan 19	**-280 Jan 30**	**-262 Feb 9**
29	-352 Jun 12	-334 Jun 24	-316 Jul 4	-298 Jul 15	-280 Jul 26	-262 Aug 6
30	-352 Dec 6	**-334 Dec 17**	-316 Dec 28	**-297 Jan 8**	-279 Jan 18	-261 Jan 30
31	-351 May 3	-333 May 14	-315 May 25	-297 Jun 5	-279 Jun 15	-261 Jun 26
32	-351 Oct 27	-333 Nov 7	-315 Nov 18	-297 Nov 29	-279 Dec 9	-261 Dec 21
33	**-350 Apr 22**	-332 May 2	-314 May 14	**-296 May 24**	**-278 Jun 4**	-260 Jun 14
34	-350 Oct 17	-332 Oct 27	-314 Nov 7	-296 Nov 18	-278 Nov 29	-260 Dec 9
35	-349 Apr 11	-331 Apr 22	-313 May 3	**-295 May 13**	-277 May 24	-259 Jun 4
36	**-349 Oct 6**	-331 Oct 16	-313 Oct 28	**-295 Nov 7**	-277 Nov 18	-259 Nov 29
37	-348 Mar 31	-330 Apr 11	-312 Apr 21	-294 May 3	-276 May 13	-258 May 24
38	**-348 Sep 24**	-330 Oct 5	-312 Oct 16	**-294 Oct 27**	-276 Nov 6	-258 Nov 18

tudes of Lunar Eclipses in Babylonian Mathematical Astronomy," *Isis* 36 (1945), 10–15, A. Aaboe and J. A. Henderson, "The Babylonian Theory of Lunar Latitude and Eclipses According to System A," *Archives Internationales d'Histoire des Sciences* 25 (1975), 181–222, and the references therein.

Table 4. (Cont.)

	13	14	15	16	17	18
1	-257 Apr 15	-239 Apr 25	-221 May 6	-203 May 17	*-185 May 28*	-167 Jun 7
2	-257 Oct 8	-239 Oct 18	-221 Oct 30	-203 Nov 9	-185 Nov 20	-167 Dec 1
3	-256 Apr 3	-238 Apr 15	**-220 Apr 25**	**-202 May 6**	-184 May 16	**-166 May 28**
4	-256 Sep 26	-238 Oct 8	-220 Oct 18	-202 Oct 29	-184 Nov 9	-166 Nov 20
5	-255 Mar 24	-237 Apr 4	**-219 Apr 14**	-201 Apr 25	-183 May 6	-165 May 17
6	**-255 Sep 16**	-237 Sep 27	-219 Oct 8	-201 Oct 19	-183 Oct 29	-165 Nov 10
7	-254 Mar 13	-236 Mar 23	-218 Apr 3	-200 Apr 13	**-182 Apr 25**	-164 May 5
8	-254 Sep 6	**-236 Sep 16**	-218 Sep 27	-200 Oct 8	-182 Oct 19	-164 Oct 29
9	**-253 Jan 31**	-235 Feb 10	*-217 Feb 22*	*-199 Mar 4*	-181 Mar 15	-163 Mar 26
10	-253 Jul 28	-235 Aug 7	-217 Aug 18	-199 Aug 29	-181 Sep 9	-163 Sep 19
11	-252 Jan 21	**-234 Jan 31**	-216 Feb 11	-198 Feb 22	**-180 Mar 4**	-162 Mar 15
12	-252 Jul 16	-234 Jul 27	-216 Aug 6	-198 Aug 18	-180 Aug 28	-162 Sep 8
13	-251 Jan 9	-233 Jan 21	-215 Jan 31	-197 Feb 11	-179 Feb 22	-161 Mar 5
14	**-251 Jul 5**	**-233 Jul 16**	-215 Jul 26	**-197 Aug 7**	-179 Aug 17	-161 Aug 28
15	-251 Dec 30	-232 Jan 10	-214 Jan 21	-196 Feb 1	-178 Feb 11	-160 Feb 23
				-196 Jul 26	-178 Aug 6	-160 Aug 17
16	-250 May 26	-232 Jun 5	-214 Jun 16			
17	-250 Nov 20	-232 Nov 30	-214 Dec 11	-196 Dec 22	**-177 Jan 2**	-159 Jan 12
18	-249 May 15	-231 May 26	-213 Jun 6	-195 Jun 16	-177 Jun 28	-159 Jul 8
19	-249 Nov 9	**-231 Nov 19**	-213 Nov 30	-195 Dec 11	**-177 Dec 22**	-158 Jan 1
20	**-248 May 4**	-230 May 15	-212 May 26	**-194 Jun 6**	-176 Jun 16	-158 Jun 28
21	-248 Oct 28	**-230 Nov 8**	-212 Nov 18	-194 Nov 30	-176 Dec 10	-158 Dec 21
22	-247 Apr 24	**-229 May 5**	-211 May 15	-193 May 27	**-175 Jun 6**	**-157 Jun 17**
23	-247 Oct 17	-229 Oct 28	-211 Nov 8	-193 Nov 19	-175 Nov 29	-157 Dec 11
24	-246 Mar 14	*-228 Mar 25*	-210 Apr 5	-192 Apr 15	-174 Apr 27	*-156 May 7*
25	-246 Sep 7	-228 Sep 17	-210 Sep 29	-192 Oct 9	-174 Oct 20	-156 Oct 31
26	-245 Mar 3	-227 Mar 14	-209 Mar 25	-191 Apr 4	-173 Apr 16	-155 Apr 26
27	-245 Aug 28	**-227 Sep 7**	-209 Sep 18	-191 Sep 19	**-173 Oct 10**	-155 Oct 20
28	-244 Feb 21	-226 Mar 3	**-208 Mar 13**	-190 Mar 24	-172 Apr 4	**-154 Apr 15**
29	-244 Aug 16	-226 Aug 27	-208 Sep 7	-190 Sep 18	-172 Sep 28	-154 Oct 10
30	**-243 Feb 9**	-225 Feb 20	-207 Mar 3	**-189 Mar 14**	-171 Mar 24	-153 Apr 5
				-189 Sep 7	-171 Sep 18	-153 Sep 29
31	-243 Jul 7	*-225 Jul 18*	-207 Jul 28			
32	-243 Dec 31	-224 Jan 11	-206 Jan 22	*-188 Feb 2*	-170 Feb 13	*-152 Feb 24*
33	-242 Jun 26	-224 Jul 6	-206 Jul 17	-188 Jul 28	-170 Aug 8	**-152 Aug 18**
34	-242 Dec 21	-224 Dec 31	-205 Jan 11	-187 Jan 22	-169 Feb 2	-151 Feb 12
35	**-241 Jun 15**	-223 Jun 25	-205 Jul 7	**-187 Jul 17**	**-169 Jul 28**	-151 Aug 8
36	**-241 Dec 10**	-223 Dec 20	-204 Jan 1	**-186 Jan 11**	-168 Jan 22	-150 Feb 2
37	-240 Jun 4	-222 Jun 15	-204 Jun 25	-186 Jul 7	**-168 Jul 17**	-150 Jul 28
38	**-240 Nov 28**	-222 Dec 9	-204 Dec 20	-186 Dec 31	-167 Jan 10	-149 Jan 22

In a typical System A lunar ephemeris, the fourth column after the date, known as column E, describes the latitude of the moon's centre. The method of calculating column E does not concern us here, but suffice it to say that it is dependent upon the elongation of the moon from the ascending node which is assumed to move in retrograde by a constant amount each month. Eclipse possibilities are defined as being the syzygy at which the lunar latitude is closest to zero. Related to column E is a column Ψ which can be

Table 4. (Cont.)

	19	20	21	22	23	24
1	-149 Jun 19	-131 Jun 29				
2	-149 Dec 12	-131 Dec 22	-112 Jan 3	-94 Jan 13	*-76 Jan 24*	-58 Feb 4
3	-148 Jun 7	-130 Jun 18	-112 Jun 29	-94 Jul 10	**-76 Jul 20**	-58 Jul 31
4	-148 Dec 1	-130 Dec 12	-112 Dec 22	-93 Jan 3	-75 Jan 13	-57 Jan 24
5	**-147 May 27**	-129 Jun 8	**-111 Jun 18**	**-93 Jun 29**	-75 Jul 9	-57 Jul 21
6	**-147 Nov 20**	-129 Dec 2	-111 Dec 12	-93 Dec 23	-74 Jan 3	-56 Jan 14
7	-146 May 16	-128 May 27	-110 Jun 7	-92 Jun 17	-74 Jun 28	-56 Jul 9
8	-146 Nov 10	**-128 Nov 20**	-110 Dec 2	**-92 Dec 12**	-74 Dec 23	-55 Jan 3
					-73 Jun 18	-55 Jun 28
9	-145 Apr 6	*-127 Apr 16*	-109 Apr 28	-91 May 8		
10	-145 Oct 1	-127 Oct 11	-109 Oct 22	-91 Nov 2	-73 Nov 13	-55 Nov 23
11	-144 Mar 26	**-126 Apr 6**	**-108 Apr 16**	-90 Apr 28	**-72 May 8**	-54 May 19
12	-144 Sep 19	-126 Sep 30	-108 Oct 10	-90 Oct 22	-72 Nov 1	-54 Nov 12
13	-143 Mar 15	-125 Mar 27	-107 Apr 6	**-89 Apr 17**	-71 Apr 28	**-53 May 9**
14	-143 Sep 8	**-125 Sep 19**	-107 Sep 29	-89 Oct 11	**-71 Oct 21**	-53 Nov 1
15	-142 Mar 5	-124 Mar 15	-106 Mar 27	-88 Apr 6	-70 Apr 17	-52 Apr 27
16	-142 Aug 28	**-124 Sep 7**	-106 Sep 19	**-88 Sep 29**	-70 Oct 11	-52 Oct 21
17	-141 Jan 24	***-123 Feb 3***	-105 Feb 14	-87 Feb 25	-69 Mar 8	-51 Mar 18
18	-141 Jul 19	-123 Jul 29	-105 Aug 10	-87 Aug 20	-69 Aug 31	-51 Sep 11
19	-140 Jan 13	**-122 Jan 23**	**-104 Feb 3**	-86 Feb 14	**-68 Feb 25**	**-50 Mar 7**
20	-140 Jul 8	-122 Jul 19	-104 Jul 30	-86 Aug 10	-68 Aug 20	-50 Aug 31
21	-139 Jan 1	-121 Jan 12	-103 Jan 22	-85 Feb 3	-67 Feb 13	-49 Feb 24
22	-139 Jun 27	-121 Jul 9	**-103 Jul 19**	-85 Jul 30	-67 Aug 10	**-49 Aug 21**
23	-139 Dec 21	-120 Jan 1	-102 Jan 12	-84 Jan 23	-66 Feb 2	-48 Feb 14
			-102 Jul 8	-84 Jul 18	**-66 Jul 30**	**-48 Aug 9**
24	-138 May 18	-120 Jul 27				
25	**-138 Nov 11**	-120 Nov 21	-102 Dec 3	-84 Dec 13	-66 Dec 25	**-47 Jan 4**
26	-137 May 7	-119 May 17	-101 May 29	-83 Jun 8	-65 Jun 19	-47 Jun 29
27	-137 Nov 1	**-119 Nov 11**	-101 Nov 22	-83 Dec 3	**-65 Dec 14**	-47 Dec 25
28	-136 Apr 25	-118 May 7	-100 May 17	-82 May 28	-64 Jun 8	-46 Jun 19
29	-136 Oct 20	-118 Oct 31	-100 Nov 11	-82 Nov 22	-64 Dec 2	-46 Dec 14
30	**-135 Apr 15**	-117 Apr 26	-99 May 7	**-81 May 18**	**-63 May 28**	-45 Jun 8
31	-135 Oct 9	-117 Oct 20	-99 Oct 31	-81 Nov 11	-63 Nov 21	-45 Dec 3
					-62 May 18	-44 May 29
32	-134 Mar 6	*-116 Mar 17*	-98 Mar 28	-80 Apr 7		
33	-134 Aug 29	-116 Sep 9	-98 Sep 20	-80 Sep 30	-62 Oct 12	-44 Oct 22
34	-133 Feb 24	-115 Mar 6	-97 Mar 17	-79 Mar 28	-61 Apr 8	-43 Apr 18
35	**-133 Aug 19**	**-115 Aug 29**	-97 Sep 10	-79 Sep 20	**-61 Oct 1**	-43 Oct 12
36	**-132 Feb 13**	-114 Feb 23	-96 Mar 6	**-78 Mar 17**	-60 Mar 27	-42 Apr 8
37	-132 Aug 7	**-114 Aug 19**	-96 Aug 29	-78 Sep 10	**-60 Sep 20**	-42 Oct 1
38	-131 Feb 1	-113 Feb 12	-95 Feb 23	**-77 Mar 6**	-59 Mar 16	-41 Mar 28
		-113 Aug 9	-95 Aug 19	-77 Aug 30	-59 Sep 10	-41 Sep 21

interpreted as the magnitude of the predicted eclipse. In System B, however, there is no column E. Instead, columns Ψ' and Ψ'' are defined which, as with column Ψ of System A, can be interpreted as the magnitude of a predicted eclipse, except that they are also calculated at syzygies for which there is no eclipse. Eclipses are predicted whenever Ψ' or Ψ'' falls within a particular range.

Table 4. (Cont.)

	25	26	27	28	29
1	-40 Feb 15	-22 Feb 26	-4 Mar 8	+14 Mar 19	+32 Mar 29
2	-40 Aug 11	-22 Aug 22	-4 Sep 1	+14 Sep 13	+32 Sep 23
3	-39 Feb 4	-21 Feb 15	-3 Feb 25	+15 Mar 9	+33 Mar 19
4	**-39 Jul 31**	**-21 Aug 11**	-3 Aug 21	+15 Sep 2	**+33 Sep 12**
5	-38 Jan 24	-20 Feb 5	**-2 Feb 15**	+16 Feb 26	+34 Mar 9
6	**-38 Jul 20**	-20 Jul 30	-2 Aug 10	**+16 Aug 21**	**+34 Sep 1**
7	**-37 Jan 14**	-19 Jan 24	-1 Feb 5	**+17 Feb 15**	+35 Feb 26
8	-37 Jul 9	-19 Jul 19	-1 Jul 31	+17 Aug 10	+35 Aug 21
9	-37 Dec 5	-19 Dec 15	-1 Dec 26	+18 Jan 6	+36 Jan 17
10	-36 May 29	**-18 Jun 10**	0 Jun 20	+18 Jul 1	+36 Jul 12
11	-36 Nov 23	-18 Dec 4	0 Dec 14	+18 Dec 26	+37 Jan 5
12	**-35 May 19**	-17 May 30	**+1 Jun 10**	**+19 Jun 21**	+37 Jul 1
13	-35 Nov 12	-17 Nov 23	+1 Dec 3	+19 Dec 15	+37 Dec 25
14	-34 May 9	-16 May 19	+2 May 30	+20 Jun 10	**+38 Jun 21**
15	**-34 Nov 1**	-16 Nov 11	+2 Nov 23	**+20 Dec 3**	+38 Dec 14
16	-33 Mar 29	-15 Apr 9	+3 Apr 20	+21 Apr 30	+39 May 11
17	-33 Sep 22	-15 Oct 3	+3 Oct 14	+21 Oct 24	+39 Nov 5
18	-32 Mar 17	-14 Mar 29	**+4 Apr 8**	+22 Apr 19	+40 Apr 30
19	-32 Sep 11	-14 Sep 22	+4 Oct 2	+22 Oct 14	+40 Oct 24
20	-31 Mar 7	-13 Mar 18	+5 Mar 28	+23 Apr 9	**+41 Apr 19**
21	-31 Aug 31	-13 Sep 12	**+5 Sep 22**	+23 Oct 3	+41 Oct 14
22	-30 Feb 24	-12 Mar 6	+6 Mar 18	+24 Mar 28	+42 Apr 8
23	-30 Aug 20	-12 Aug 31	**+6 Sep 11**	+24 Sep 21	+42 Oct 3
24	-29 Jan 15	-11 Jan 26	+7 Feb 6	+25 Feb 16	+43 Feb 28
25	-29 Jul 11	-11 Jul 21	+7 Aug 1	+25 Aug 12	+43 Aug 23
26	**-28 Jan 5**	-10 Jan 15	+8 Jan 27	**+26 Feb 6**	+44 Feb 17
27	-28 Jun 29	-10 Jul 10	+8 Jul 21	+26 Aug 1	+44 Aug 11
28	-28 Dec 24	-9 Jan 5	+9 Jan 15	+27 Jan 26	+45 Feb 6
29	**-27 Jun 19**	**-9 Jun 30**	+9 Jul 10	+27 Jul 22	**+45 Aug 1**
30	-27 Dec 13	-9 Dec 25	+10 Jan 4	+28 Jan 15	+46Jan 25
31	-26 Jun 8	**-8 Jun 19**	+10 Jun 30	+28 Jul 10	+46 Jul 22
32	-26 Nov 2	-8 Nov 13	+10 Nov 24	+28 Dec 5	+46 Dec 16
33	-25 Apr 30	-7 May 10	+11 May 21	+29 Jun 1	+47 Jun 12
34	**-25 Oct 23**	-7 Nov 2	+11 Nov 14	**+29 Nov 24**	+47 Dec 5
35	-24 Apr 18	**-6 Apr 29**	+12 May 9	+30 May 21	+48 May 31
36	-24 Oct 12	**-6 Oct 23**	+12 Nov 2	+30 Nov 14	+48 Nov 24
37	**-23 Apr 7**	-5 Apr 18	+13 Apr 28	+31 May 10	+49 May 20
38	-23 Oct 1	-5 Oct 13	+13 Oct 23	+31 Nov 3	+49 Nov 14

The earliest System A lunar ephemeris has been dated to −318,[52] and scattered examples are preserved down to the middle of the first century BC. Amazingly, these texts

[52] A. Aaboe, "A Computed List of New moons for 319 BC to 316 BC from Babylon: BM 40094," *Det Kongelige Danske Videnskabernes Selskab Matematisk-fysiske Meddeleser* 37/3 (1960).

have been found to be connectable; in other words, extrapolating from one text using the rules of System A we eventually arrive at another text with no discontinuities. It is therefore possible to compute a complete System A lunar ephemeris over any required period, and so, in turn, to compute all of the eclipses predicted by System A. This reveals that a small, but none the less significant, number of lunar eclipse predictions recorded in the NMAT texts would not have been predicted by System A. For example, a Diary fragment for −129 (Rm 701+ BM 41478 + 41646 Obv. 7′), sadly rather damaged, records a prediction on May 24:

> Night of the 14th, . . . lunar eclipse, 5 months, . . . omitted, at [. . .]

However, according to System A, this eclipse would have been predicted a month later, six months after the previous eclipse. Similarly, a number of solar eclipses which are predicted in the NMAT texts are not predicted by System A. As we would expect, these all occur at eclipse possibilities on the five month boundaries.

System B lunar ephemerides, which are attested from −205 to −74, are not connectable from one text to the next. This means that it is not possible to recalculate a complete list of lunar eclipse possibilities as was the case for System A. Only those dates which are attested in System B texts and in NMAT texts can therefore be compared and, unfortunately, this only occurs on seven dates. On each occasion a lunar eclipse was indeed predicted. However, when we consider the solar eclipses, then there is a case of an eclipse not being predicted by System B that is recorded in an NMAT text. The is the eclipse possibility of −131 February 1 which is recorded in a Diary fragment (LBAT 441 Rev. 10′) as occurring after five months, but is not predicted in the ephemeris ACT 120.

The second question facing the Babylonian astronomers was how to predict the time of the eclipse. As mentioned above, the predicted times recorded in the NMAT texts relate to the moment when the eclipse was expected to begin. This immediately suggests that the Saros cycle was being used to predict the times of the eclipses as well as the dates on which they were to occur, for this is the only short period eclipse cycle in which eclipses recur that have similar magnitudes and durations. When observing eclipses, the Babylonians always timed the moment of first contact. By adding one Saros on to this time they would arrive at the time of first contact for the next eclipse. The utility of the Saros for predicting times of first contact was shown in Table 1. Clearly, the local time of an eclipse increases by about 8 hours, or one third of a day, for every eclipse. However, the situation is complicated by the fact that the Babylonians recorded times not relative to midnight as we do, but as a time interval, measured in UŠ corresponding to the Greek time-degree, before or after sunset or sunrise. Thus, they also had to take into account the change in the length of day and night when they predicted their eclipse times. There are a number of ways they may have done this. For example, *Enūma Anu Enlil* tablet 14,[53] parts of MUL.APIN,[54] i.NAM.giš.hur.an.ki.a,[55] and other texts give schemes for

[53] F. N. H. Al-Rawi and A. R. George, "Enūma Anu Enlil XIV and Other Early Astronomical Tables," *Archiv für Orientforschung* 38–39 (1991–1992), 52–73.

[54] H. Hunger and D. Pingree, *MUL.APIN: An Astronomical Compendium in Cuneiform*, Archiv für Orientforschung Beiheft 24 (Horn, 1989).

[55] A. Livingstone, *Mystical and Mythological Explanatory Works of Assyrian and Babylonian Scholars* (Oxford University Press, Oxford, 1986).

calculating the length of daylight. These may be divided into two basic groups: those that assume a ratio of 2:1 for the longest to the shortest night, and those that assume a ratio of 3:2.[56] The exact method which was used will almost certainly never be known, although it was probably based upon simply adding something like 120 UŠ onto the time of an eclipse eighteen years earlier, and then adjusting for the length of daylight. After I had come to this conclusion, Lis Brack-Bernsen informed me that the text TU 11 contains just such a set of simple rules for calculating eclipse times using the Saros cycle.[57]

A part of this text, which also contains rules for calculating the lunar six and various astrological information, explains how the expected time of an eclipse in Month I can be obtained from the time of an eclipse eighteen years ago simply by adding one-third of a day onto the earlier time. Since in the ideal Babylonian calendar the middle of Month I is the date of the spring equinox, the length of the day and night are both assumed to be 180 UŠ, and so it is easy to calculate this time relative to sunrise or sunset. However, this part of the text does not explain what to do at other times of the year when the day and night are not of equal length. When discussing the lunar six, the 2:1 ratio for longest to shortest night is implied, and so a scheme based upon this ratio seems to be the most likely solution. I therefore constructed a simple scheme along these lines, but it was not possible to replicate the exact predicted times in the NMAT texts. Using a scheme based upon the 3:2 ratio the discrepancies were smaller, but still present. I would therefore suggest that a scheme similar to that implied by TU 11, but probably using the 3:2 ratio for the longest to the shortest night, and possibly also a better approximation than 120 UŠ for the excess of the Saros over one day, was used to obtain the times.

This is not the end of the story, however. For whenever the Saros was revised, there would be one or two eclipses that had no precursor a Saros earlier. Clearly the expected times of these eclipses could not have been calculated using the Saros. Perhaps in these cases the times were estimated by the same rough means used by the Assyrian scholars; i.e., by observing the length of time the sun and moon were visible together on the day of the eclipse. From TU 11 it would seem that the lunar six measurements could have been used to calculate the time of opposition and conjunction.[58] However, this would not have yielded the time of the beginning of the eclipse generally found in the records.[59]

Finally, let me remark that it is clear that the ACT texts were not used to predict the times of the eclipses, despite the fact that calculating the times and visibilities of the syzygies was one of the goals of the Babylonian mathematical astronomy. Both System A and System B contain a column M giving the time of syzygy with respect to either sunset (System A) or sunset or sunrise (System B). However, neither system appears to

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[56] See, most recently, D. Brown, J. Fermor and C. Walker, "The Water Clock in Mesopotamia," *Archiv für Orientforschung* (forthcoming) with references to earlier discussions.

[57] A copy of TU 11 (=AO 6455) was published by F. Thureau-Dangin, *Tablettes d'Uruk,* Textes Cunéiform du Louvre 6 (Paris, 1922). A full edition with translation and commentary is currently being prepared by H. Hunger and L. Brack-Bernsen.

[58] See L. Brack-Bernser, "Goal-Year Tablets: Lunar Data and Predictions," in N. M. Swerdlow (ed.) *Ancient Astronomy and Celestial Divination* (The MIT Press, Cambridge, forthcoming).

[59] A more detailed discussion of the possible role of the lunar six in predicting eclipses will have to wait for further investigations of TU 11 and related texts.

Table 5. A selection of eclipse times calculated by Systems A and B compared with those recorded in the NMAT texts. Dashes relate to eclipse possibilities where there are no preserved ACT texts for comparison

Date	Recorded Time	System A Time	System B Time
−164 Oct 29 (solar)	64° after sunset	50° after sunset	–
−131 Jan 17 (lunar)	60° after sunset	–	81° after sunset
−131 Feb 1 (solar)	21° after sunset	–	Not Predicted
−102 Jul 8 (solar)	30° before sunset	13° before sunset	14° before sunset

allow the duration of an eclipse, and hence the time of first contact given in the predicted records, to be calculated. It is possible, of course, that column Ψ, which characterizes the magnitude of an eclipse, could be manipulated in some way to obtain the duration. [60] Indeed, Text S contains a function related to the magnitude which it has been suggested may be a calculated duration.[61] This is only an isolated case, however, and on the whole there is no evidence that eclipse durations were calculated in Babylonian mathematical astronomy. Unsurprisingly, therefore, the times given by Systems A and B are very different from those recorded in the NMAT texts (some examples are shown in Table 5). Taken together with the fact that Systems A and B do not even predict all of the eclipses for which there are records in the NMAT texts, it seems clear that the ACT methods were never used in making eclipse predictions for the Diaries and related texts.

Epilogue

To summarize the preceding two sections, it would appear that throughout the last seven or eight centuries BC, the astronomers in Mesopotamia used simple period relations to predict the dates of eclipses of the sun and moon, be they the basic five and six month intervals between eclipse possibilities identified by the Assyrian scholars or the more advanced schemes involving the Saros cycle used by the Babylonian astronomers. Eclipse times were also predicted using simple methods based either upon the Saros cycle, or upon crude estimates of the difference in longitude of the moon and sun from observations of the length of time the two luminaries were seen together on the day of the eclipse. These methods – let me call them empirical schemes since they are based upon observed period relations rather than any mathematical theory – contin-

[60] Chinese astronomers of the first millennium AD used simple relationships between magnitude and duration in their calendrical systems. For example, in the *Ta-yen-li* magnitudes were calculated on a scale of 1 to 15, and from these the duration of a lunar eclipse was obtained by adding to it 2 *k′o* if the magnitude was less than 5, 4 *k′o* if it was less than 10, and 5 *k′o* if it was greater than 10. For solar eclipses, 2 *k′o* was simply added to the magnitude to give the duration. The *k′o* was a unit of time such that there are 100 *k′o* in a day. For details, see K. Yabuuti, "Astronomical Tables in China from the Han to the T'ang Dynasties," in K. Yabuuti (ed.), *Chūgoku Chūsei Kagaku Gijutsushi No Kenkyū* (Tokyo, 1963) 445–492.

[61] K. P. Moesgaard, "The Full Moon Serpent: A Foundation Stone of Ancient Astronomy," *Centaurus* 24 (1980), 51–96.

Table 6. The local time of conjunction according to System A, System B and Goldstine

Date	ACT 15 (System A)	ACT 122 (System B)	Goldstine
−102 Apr 10	20.89	21.76	20.16
−102 May 10	11.48	11.86	10.78
−102 Jun 9	3.38	3.36	2.00
−102 Jul 8	18.26	18.20	17.23
−102 Aug 7	7.38	8.27	7.78
−102 Sep 5	18.89	21.68	21.25
−102 Oct 5	8.37	11.08	9.70
−102 Nov 3	20.37	23.77	21.45
−102 Dec 3	7.17	11.04	8.75
−101 Jan 1	17.87	21.27	19.63
−101 Jan 31	4.67	7.13	6.05
−101 Mar 1	16.37	18.30	16.25
−101 Mar 31	3.79	4.81	2.73

ued being used despite the development of mathematical astronomy in the Achaemenid period.

This brings us to the interesting question of why the (generally assumed superior) ACT methods for predicting eclipses were not adopted, a question for which the answer is far from clear. One possibility is simply that the astronomers who compiled the Diaries did not have a sufficient understanding of the working of the mathematical astronomy to use it on a day to day basis. However, this seems unlikely as it would appear that some of the astronomers who compiled the ACT ephemerides may have been the very same astronomers who were employed to keep the Diaries.[62] The answer may instead be that there was simply no need to use the ACT methods. If the purpose of the predictions was to guide the astronomers as to when it was necessary to make observations, then the empirical schemes are perfectly adequate, and one reason for recording the predictions in the Diaries may just have been to keep track of the months which were considered eclipse possibilities. Obviously, the predictions also had astrological importance – whether they were being interpreted as omens from the series *Enūma Anu Enlil* or were forming part of a horoscope – and in both cases only rough estimates of the time of the eclipse would be needed. Again, preparations for the various eclipse rituals only required an idea of the time that the eclipse was expected to begin. As I have shown, the empirical schemes that were used were quite capable of fulfilling these various requirements without the astronomers having to resort to the more complicated methods of mathematical astronomy.

In addition, we have to wonder whether the ACT scheme for calculating eclipses *were* actually superior to the empirical methods of prediction. At least for eclipses this may not have been the case. In Table 6 I have compared the times of conjunction for

[62] On these individuals, see F. Rochberg, "The Cultural Locus of Astronomy in Late Babylonia," in H. D. Galter (ed.), *Die Rolle der Astronomie in den Kulturen Mesopotamiens* (Grazer Morgenländische Studien, Graz, 1993), 31–45 and "Scribes and Scholars: the *ṭupšar Enū*ma *Anu Enlil*," in H. Neumann (ed.), *Fs. Oelsner* (Berlin, forthcoming).

SE 209 calculated by Systems A and B, found on ACT 15 and ACT 122 respectively, with times taken from Goldstine.[63] Clearly there can be a considerable error in the time of conjunction calculated by these methods, ranging up to about 2.5 hours.[64] I should also point out that comparison of other ACT texts with Goldstine also reveals errors in the calculated time of conjunction up to (and occasionally even greater than) 2.5 hours. A typical value of the error in the time of conjunction (or opposition) is between about 1 and 1.5 hours. When the Babylonian astronomers were predicting the time of the beginning of the eclipse, they generally obtained times that were accurate to between 1 and 2 hours for the eclipses we could expect them to have then been able to observe.[65] The accuracy of the ACT methods in calculating the time of syzgy was therefore not significantly better than the times of eclipses predicted using their empirical methods. When we consider that the clocks used to time eclipses were only accurate to about 0.5 hours for time intervals of about 3 hours,[66] it is very unlikely that the Babylonian astronomers would have been able to detect any difference between the accuracy of the ACT systems and the empirical methods that they used. Remembering also that the time of syzygy provided by Systems A and B was not the time of first contact, which it seems is what they wanted from their predictions, we should not be surprised to find that the ACT schemes were not used to make the eclipse predictions for the Diaries.

These are doubtless only some of the reasons why the eclipse predictions in the Diaries were not made using the ACT schemes. It should also be noted, for example, that there is very little evidence of any of the predictions of planetary phenomena recorded in the Diaries having been made by the ACT methods.[67] The whole question of the relationship between the Diaries and other NMAT texts and the ACT texts, and of what the various texts were "for," has yet to be satisfactorily addressed.[68] For the present, therefore, all we can say is that it seems likely that the empirical schemes for predicting eclipses were used in part simply because there was no need to use the more complicated, and not necessarily superior, ACT methods.

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[63] H. H. Goldstine, *New and Full Moons 1001 BC to AD 1651* (American Philosophical Society, Philadelphia, 1973). Goldstines times contain some error due to his not making sufficient allowance for long-term variations in the Earth's rate of rotation, but this is generally less than about 0.2 hour which is insignificant for the present purposes.

[64] This is partly caused by the convention of recording the time relative to sunrise or sunset. Both System A and System B ephemerides have a column C which contains the supposed length of the day at each syzygy. This column is based upon the ratio of 3:2 for the longest to the shortest night, which is not exact for Babylon. Errors in column C are propagated directly to column M, the time of syzygy. See O. Neugebauer, *A History of Ancient Mathematical Astronomy* (Springer-Verlag, Berlin, 1975), 366–371.

[65] J. M. Steele and F. R. Stephenson, "Lunar Eclipse Times Predicted by the Babylonians," *Journal for the History of Astronomy*, 28 (1997) 119–131 and J. M. Steele, "Solar Eclipse Times Predicted by the Babylonians," *Journal for the History of Astronomy*, 28 (1997) 131–139.

[66] J. M. Steele, F. R. Stephenson and L. V. Morrison, "The Accuracy of Eclipse Times Measured by the Babylonians," *Journal for the History of Astronomy*, 28 (1997) 337–345.

[67] A. J. Sachs and H. Hunger, *Astronomical Diaries and Related Texts from Babylon, Volume I* (Österreichischen Akademie der Wissenschaften, Vienna, 1988), 25.

[68] I hope discuss some of these questions in detail in a forthcoming article.

Acknowledgments. I am deeply indebted to Christopher Walker for initially suggesting that I attempt to reconstruct the various Saros schemes, and to Hermann Hunger for his encouragement and for making available to me his editions of the eclipse texts in advance of publication. I also wish to thank John Britton, Alexander Jones, and Lis Brack-Bernsen for several useful discussions during the writing of this paper. This research was made possible by a fellowship from the Dibner Institute for the History of Science and Technology. I am pleased to record my thanks for that award here.

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(Received November 9, 1999)