COUNTING DAYS IN ANCIENT BABYLON: ECLIPSES, OMENS, AND CALENDRICS DURING THE OLD BABYLONIAN PERIOD (1750-1600 BCE)

by

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ABSTRACT

STEVEN JEDAEL. Counting days in ancient Babylon: eclipses, omens, and calendrics during the Old Babylonian period (1750-1600 bce).
(Under the direction of DR. JOHN C. REEVES)

Prior to the sixth century BCE, each lunar month of the Babylonian calendar is believed to have been determined solely by direct observation of the new moon with the insertion of intercalary months arbitrarily dictated by the king and his advisors. However, lunar eclipse omens within the divination texts of the *Enūma Anu Enlil*, some which date to the second half of the Old Babylonian period (ca. 1750-1600 BCE), clearly indicate a pattern of lunar eclipses occurring on days 14, 15, 16, 20, and 21 of the lunar month—a pattern suggesting an early schematic structure. In this study, I argue that observed period relations between lunar phases, equinoxes, and solstices as well as the invention of the water clock enabled the Babylonians to become aware of the 8-year lunisolar cycle (known as the *octaeteris* in ancient Greece) and develop calendars with standardized month-lengths and fixed rules of intercalation during the second millennium BCE.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABC	Grayson, A. K. *Assyrian and Babylonian Chronicles*
ABCD	Rochberg-Halton, F. *Aspects of Babylonian Celestial Divination*
ABL	Harper, R. F. *Assyrian and Babylonian Letters*
BM	Tablets in the collections of the British Museum, London
EAE	*Enūma Anu Enlil*
LAS	Parpola, S. *Letters from Assyrian Scholars to the Kings Esarhaddon and Assurbanipal I, II*
LBAT	Sachs, A. J. *Late Babylonian Astronomical and Related Texts*
MUL.APIN	Hunger, H. and D. Pingree. *MUL.APIN: An Astronomical Compendium in Cuneiform*

Other Abbreviations & Symbols

OB	Old Babylonian
obv.	obverse
r., rev.	reverse
var.	variant
$^?$, (?)	uncertain reading
( )	parentheses enclose additions in the translation
…	an ellipsis marks a gap in the text or untranslatable word(s)
[ ]	brackets enclose restorations
[…]	minor break (one or two missing words)
^ / ¯	a circumflex or macron indicates a long vowel
ḥ	*h* with underdot represents a fricative *h* sound not found in English
ḫ	*h* with underbreve indicates a sound like “kha”

ṣ	*s* with underdot represents an emphatic *s* sound not found in English
ś	*s* with acute accent represents a lateral *s* sound not found in English
š	*s* with hacek indicates a sound like the English *sh*
ṭ	*t* with underdot represents an emphatic *t* sound not found in English

LIST OF STANDARD MESOPOTAMIAN MONTHS
(SUMERIAN LOGOGRAPHIC SPELLINGS)

Nisannu (ITI.BARA$_2$/BAR)	Month I	(March-April)
Ajaru (GU$_4$)	Month II	(April-May)
Simānu (SIG)	Month III	(May-June)
Tamūzu/Du'ūzu (ŠU)	Month IV	(June-July)
Abu (NE)	Month V	(July-August)
Elūlu/Ulūlu (KIN)	Month VI	(August-September)
Tašrītu (DU$_6$)	Month VII	(September-October)
Araḫsamnu (APIN)	Month VIII	(October-November)
Kislīmu (GAN)	Month IX	(November-December)
Ṭebētu (AB)	Month X	(December-January)
Šabāṭu (ZÍZ)	Month XI	(January-February)
Addaru (ŠE)	Month XII	(February-March)
Addaru arkû (ŠE.DIRI)	Intercalary Month XII2	

CHAPTER 1: INTRODUCTION

Chaos is merely order waiting to be deciphered.

—José Saramago, *The Double*

Within the study of astronomical texts from the ancient Near East and Mediterranean, there remains a persistent narrative that science, mathematics, and consequently astronomy did not exist before Thales of Miletus (ca. 624-546 BCE). Prior to Thales, observations concerning the cosmos are thought to be mired in magic and the supernatural, relying exclusively on visual confirmations without any broader understanding of the mathematical relationships between celestial objects. It is Thales and the pre-Socratic philosophers that followed who are depicted as initiating order to Western civilization's knowledge of the cosmos when beforehand there was only chaos.

Based on the knowledge gathered from inscriptional texts, it is clear that observed cycles of various celestial bodies formed the basis of calendar developments within the ancient Near East; and similarly, the narrative regarding calendrical innovations has followed closely with that of astronomy as highlighted above. For example, the *octaeteris* or 8-year cycle has an unknown origin but is attributed to Greek astronomers in the sixth or early fifth centuries BCE. Meton of Athens is credited with discovering an alternative 19-year lunisolar cycle (in which 19 solar years closely equal 235 lunar months), introducing this "Metonic" cycle to the Attic calendar in 432 BCE. Most scholars now acknowledge that the Babylonians were aware of both cycles by the beginning of the Persian Achaemenid period (ca. 541 BCE); nevertheless, the overwhelming consensus is that the Babylonians had neither made use of these fixed cycles nor instituted any fixed system for month lengths or the insertion of intercalary months prior to the mid-sixth century BCE—again not until after Thales.[1] All Babylonian calendar months before this period are currently believed to have been determined solely by direct or anticipated observation of the new moon with the insertion of intercalary months (extra months inserted periodically into the calendar year in order to harmonize it with the solar year) left completely to the discretion of the king and his advisors.[2] This position, of course, is not without support. Some of the most sequential lunar observations within Babylonian astronomical texts date to the reign of Nebuchadnezzar II (ca. 605-562 BCE), yet these observations at present reveal no discernable preset structure. However, lunar eclipse omens within the divination texts of the *Enūma Anu Enlil*, some which date as early as the second half of the Old Babylonian period (ca. 1750-1600 BCE), clearly indicate a pattern of lunar eclipses occurring on days 14, 15, 16, 20, and 21 of the lunar month—a pattern suggesting an early embedded structure to the Babylonian calendar.[3]

In this study, I argue that calendar developments during the Old Babylonian period can be best characterized as annual alternations of 29-day or 30-day month lengths with solstices in relation to the new moon determining when intercalary months were needed. The advent of the water clock in Babylonia enabled the consistent detection of cardinal phenomena (i.e. equinoxes and solstices) so that the latter could be used in

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[1] Sacha Stern, *Calendars in Antiquity: Empires, States, and Societies* (Oxford: Oxford University Press, 2012), 50-110.

[2] John M. Steele, "Mesopotamian Calendars," in *Handbook of Archaeoastronomy and Ethnoastronomy*, ed. Clive L. N. Ruggles (New York: Springer, 2015), 1844.

[3] Francesca Rochberg-Halton, *Aspects of Babylonian Celestial Divination: The Lunar Eclipse Tablets of Enūma Anu Enlil*, Archiv für Orientforschung Beiheft 22 (Horn: Verlag Ferdinand Berger & Söhne, 1988), 38.

tandem with lunar phases to stabilize the summer solstice, autumnal equinox, winter solstice, and vernal equinox in months III, VI, IX, and XII of the calendar respectively. I maintain that the goal of Babylonian astrologers was simple: to develop a system of time reckoning that would satisfy the religious, political, and economic needs of their empire. My goal is to demonstrate that the Babylonians were aware of the 8-year lunisolar cycle and employing fixed rules of intercalation more than a thousand years prior to the sixth century BCE.

1.1. Textual Sources

This study relies on ancient Near Eastern inscriptions from divinatory and magical omens, astronomical records, administrative correspondences, and the chronicles of Babylonian and Assyrian rulers. Authorship of these sources can be credited to a class of individuals known in the Neo-Assyrian period as the *ummânu*, which consisted of diviners, magicians, scribes, and other experts tasked with informing the king of all pertinent matters related to the empire. These individuals and their activities are collectively referred to as the "protection" (*maṣṣartu*) within the source material; and it is in this context that astronomy, omens, and calendrics all intertwine to serve in the day to day politics and administration of the state.[4]

1.1.1. Enūma Anu Enlil

The *Enūma Anu Enlil* is a collection of omens believed to be canonized during the Kassite period (1595-1157 BCE) and referenced afterwards by astrologers for more than a millennium. Although the entire omen series has yet to be fully reconstructed by scholars, the celestial omens pertaining to lunar eclipses, which Francesca Rochberg

[4] Lorenzo Verderame, "Astronomy, Divination, and Politics in the Neo-Assyrian Empire," in *Handbook of Archaeoastronomy and Ethnoastronomy*, ed. Clive L. N. Ruggles (New York: Springer, 2015), 1849.

translates in *Aspects of Babylonian Celestial Divination*, provide more than enough material for this study. All omens in the *Enūma Anu Enlil* consist of a basic *if-then* conditional such that if one event occurs or has occurred, then a second event will also occur. The dependent clause or *protasis* of the omen contains a direct observation of the physical world such as, "if the (lunar) eclipse occurred on day *x* of month *y* and fraction *z* of the moon was covered…." The main clause or *apodosis* of the omen contains a prediction of a future event, either favorable (e.g., military victory and economic prosperity) or unfavorable (e.g., plague and famine), that would impact the king, empire, or surrounding nations.

Modern scholarship holds that the Babylonians perceived the linkage between protases and apodoses to be correlational as opposed to causal; but one should definitely not assume this linkage is the result of simultaneous or sequential observations. Rochberg presents several cases in which protases and apodoses in celestial omens are completely formulaic, with even linguistic or conceptual associations organized into specific schemata. Consequently, the observations of the *Enūma Anu Enlil* are generally ignored as sources of datable astronomical phenomena.[5] What distinguishes this study from other projects regarding Babylonian calendrics is that I have focused on the protases of lunar eclipse omens in the *Enūma Anu Enlil* not as sources of datable material but as indicators of the structure of Babylonian time-reckoning schemata.

1.1.2. MUL.APIN

The MUL.APIN, named after its incipit constellation—"the plough", consists of more than 200 astronomical observations written in cuneiform on a pair of clay tablets.

[5] Francesca Rochberg, *The Heavenly Writing: Divination, Horoscopy, and Astronomy in Mesopotamian Culture* (Cambridge: Cambridge University Press, 2004), 256-271.

The earliest known copy dates to 686 BCE; however, Hermann Hunger and David Pingree argue that the text was finalized circa 1000 BCE.[6] While the first tablet focuses primarily on the rising and setting of various constellations and planets, the second tablet is of particular interest for this study because it illustrates the use of equinoxes and solstices to stabilize the Babylonian calendar as well as the water clock and gnomon to measure the lengths of day and night for each astronomical event.

1.1.3. Astronomical Diaries

The Astronomical Diaries are a collection of cuneiform tablets which provide direct evidence that the Babylonians perceived some astronomical phenomena to be periodic. As a result, they represent a systematic attempt on the part of astrologers to observe and organize these phenomena within a structured framework. In his "Classification of the Babylonian Astronomical Tablets," Abraham Sachs coins the term "Diaries" for this category of texts because of the daily recordings of lunar and planetary positions inscribed on the tablets.[7] Securely datable tablets range from the mid-seventh to the mid-first centuries BCE; however, it is evident that diary entries were recorded one hundred years prior during the reign of Nabonassar (747-734 BCE) given Ptolemy's claim in his *Almagest* (c.a. 150 CE) that the Nabonassar's reign "is the era beginning from which the ancient observations are, on the whole, preserved down to our time."[8] Unlike the *Enūma Anu Enlil*, the Diaries contain very few omens, consisting mainly of direct observations, predictions, and computations. Hunger and Pingree thus argue that

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[6] Hermann Hunger and David Pingree, *MUL.APIN: An Astronomical Compendium in Cuneiform, AfO* Supplement 24 (Horn, Austria: Ferdinand Berger & Söhne, 1989), 11-12.

[7] A. Sachs, "A Classification of the Babylonian Astronomical Texts of the Seleucid Period," *Journal of Cuneiform Studies* 2, no. 4 (1948):285-286.

[8] *Almagest* III, 7. See also G. J. Toomer, *Ptolemy's Almagest* (Princeton: Princeton University Press, 1998), 166.

the Diaries represent the inception of Babylonian sky-watching as a scientific endeavor.[9] For this study, I focus on lunar eclipse entries from eight tablets stored at the British Museum: BM 41985 (*LBAT* 1413), BM 32238 (*LBAT* 1414), BM 35115 (*LBAT* 1415, 1416, 1417), BM 32234 (*LBAT* 1419), BM 38357, BM 38462 (*LBAT* 1420), BM 41536 (*LBAT* 1421), and BM 36879.[10] Several entries in the aforementioned tablets record the actual regnal year, month, and day of the eclipse, making the Diaries indispensable in deciphering and validating the structure of the Babylonian calendar.

1.1.4. Letters from Assyrian Scholars

Additional omens and astronomical observations can be found in a collection of letters and reports addressed to the Neo-Assyrian kings Esarhaddon (ca. 680-669 BCE) and Assurbanipal (ca. 668-627 BCE). Hunger and Simo Parpola have most recently been pivotal in translating and organizing this corpus.[11] The authors of these tablets are various members of the literati residing throughout Assyria and Babylonia whose primary objective no doubt was to obtain or maintain political favor with the king.

Letters differ from reports in that they address the king directly. Favorable omens from the *Enūma Anu Enlil* are often cited in the letter introductions followed by proposed actions that the king should make in gratitude to the gods. Many letters, however, include unfavorable omens such as those associated with lunar eclipses. In such instances, the letter is meant to serve both as a warning and prescription for rituals to be performed by

[9] Hermann Hunger and David Pingree, *Astral Sciences in Mesopotamia* (Leiden: Brill, 1999), 144.

[10] For translations, see Hermann Hunger, ed., *Astronomical Diaries and Related Texts from Babylonia*, vol. 5, *Lunar and Planetary Texts* (Wien: Osterreichische Akademie Der Wissenschaften, 2001), 2-34.

[11] For translations, see Hermann Hunger, *Astrological Reports to Assyrian Kings* (1992; repr., Winona Lake, IN: Eisenbrauns, 2014) and Simo Parpola, *Letters from Assyrian Scholars to the Kings Esarhaddon and Assurbanipal*, 2 vols, (1970-83; repr., Winona Lake, IN: Eisenbrauns, 2007-09).

the king to counteract potential evil portents. Reports, on the other hand, are usually submitted one of the king's advisors or correspondents and are free of any proposed actions, in most cases consisting of only an omen understood to be related to a recent observation.[12] Both types of correspondences, nevertheless, are replete with astronomical observations (whether directly mentioned or implied via cited omen) that permit absolute dating of the phenomena referenced.

1.2. Theory and Method

This project is grounded in middle-range theories and approaches commonly applied in the fields of ethnohistory and experimental archaeology, specifically the direct historical approach. Developed in the United States of America between the 1920s and 1930s, the direct historical approach argues that knowledge related to known historical periods can be extrapolated (under certain conditions) to earlier times when little or no historical records exist. Historical data from one context is used to explain data found in another, providing an *analogy* to illuminate additional insights. The key requirement of the direct historical approach is the presence of continuity, whether cultural or geographical, between two or more contexts.

It is without question that the Babylonian calendar was the most widely used time-reckoning system of the ancient Near East since the empires of the Assyrians, Babylonians, Persians, and Seleucids (Hellenistic) all adopted it as their imperial calendar with subtle variations. Furthermore, most scholars acknowledge that the Metonic cycle of the fifth century BCE was inspired directly or indirectly by the Babylonian calendar. Methods for time reckoning in Hellenistic writings such as Hesiod's *Works and Days* and

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[12] Hunger and Pingree, *Astral Sciences*, 23-26.

the Hippocratic medical writings bear striking similarities to those in the MUL.APIN, suggesting that certain calendrical methods had been known and widespread for centuries throughout the ancient Near East.[13] Therefore, the continuity and influence of the Babylonian calendar in eastern Mediterranean cultures makes it an ideal candidate for such an approach, with inscriptions of calendric methods from later periods enabling us to extract remnants of rationale employed in earlier ones.

According to Anthony F. Aveni, researchers in the field of archaeoastronomy should never forget that "they are dealing with real people, whose astronomy can only be said to known and understood when its level of practice is commensurate with whatever we know from the material record of the culture."[14] Experimental archaeology as a form of actualistic study (the use of observations and practices in the present to understand past dynamics) excels at uncovering the nuances of ancient practices. For example, archaeologists engaged in the experimental manufacture and the handling of stone tools routinely use the debris and examination of wear from such exercises to identify stone tools within the archaeological record.[15] The following chapters and appendices of this project represent experimental exercises in the enterprise of calendrics. They are the result of attempts to replicate ancient Mesopotamian time reckoning methods based upon known technologies from the archaeological record, specifically the use of the Babylonian water clock and the simple counting of days. Such exercises illuminate the

[13] Alexander Jones, "Transmission of Babylonian Astronomy to Other Cultures," in *Handbook of Archaeoastronomy and Ethnoastronomy*, ed. Clive L. N. Ruggles (New York: Springer, 2015), 1878.

[14] Anthony F. Aveni, *Archaeoastronomy in the New World* (Cambridge: Cambridge University Press, 1982), vii.

[15] Matthew Johnson, *Archaeological Theory: An Introduction*, 2nd ed. (Malden, MA: Wiley-Blackwell, 2010), 53-54.

numerous challenges Babylonian astrologers would have faced in maintaining a calendar as well as strategies for their resolution.

Dates for lunar phases, lunar eclipses, equinoxes, and solstices have been reproduced using algorithms developed by Jean Meeus.[16] I also have made great effort to determine the local observability of the astronomical phenomena listed above within the ancient Near East and have used Delta T (ΔT) adjustments from L. V. Morrison and F. R. Stephenson as a result.[17] Once dates for the phenomena were calculated, I experimented with various time reckoning schemata, conforming to the guidelines consistently reported in the lunar eclipse omen texts in order to replicate Babylonian date patterns for lunar eclipses recorded in the *Enūma Anu Enlil* and Astronomical Diaries. Finally, schemata were evaluated against intercalary months attested by inscriptions from chronicles and administrative correspondences within the periods of study.

1.3. Overview of Study

Chapter 2 contains a brief overview of lunisolar phenomena and calendric issues that Babylonian astrologers would have faced in reconciling lunar and solar cycles. I also explain features of the *octaeteris* and Metonic cycles in order to introduce strategies for addressing these issues, namely period relations between principal lunar phases and cardinal phenomena.

In chapter 3, I highlight evidence concerning the use of the Babylonian water clock in the *Enūma Anu Enlil* as well as potential clock designs as theorized by modern

[16] See Jean Meeus, *Astronomical Algorithms*, 2nd ed. (Richmond, VA: Willmann-Bell, 2009).

[17] Variations in the Earth's rate of rotation can result in minute changes to the length of day. These changes accumulate over millennia with their net total referred to in astronomy as Delta T (ΔT). The impact of ΔT can be significant for retrospective computations of solar and lunar positions in the first and second millennium BCE. For example, the value of ΔT around 1000 BCE is as much as 7 hours. See L.V. Morrison and F. R. Stephenson, "Historical Errors of the Earth's Clock Error ΔT and the Calculation of Eclipses," *Journal for the History of Astronomy* 35, no. 3 (August 2004): 332.

scholars. In addition to addressing the issues of viscosity and capillarity that possibly impacted the clock’s accuracy, I propose a significantly smaller two-stage design of the water clock consisting of wooden vessels that are cubic in dimension. The ability of astrologers to detect and measure equinoxes and solstices via the water clock is also examined, with special attention given towards lengths of daylight and darkness recorded in ideal calendar schemes of the Old Babylonian period.

I attempt in chapter 4 to ascertain the circumstances under which month lengths and intercalary months would have been determined with the goal of establishing a set of rules for intercalation. Special consideration is given towards Peter J. Huber’s analysis of the Venus Tablet of Ammi-saduqa for clues into reconstructing Old Babylonian calendar schemes.

Finally, I conclude this study by summarizing all of its major findings and detailing potential implications in the synchronization of ancient Near Eastern chronologies. The question as to whether the birth of astronomy should be credited to Babylonian astrologers remains a hotly debated topic. As a result, I make final remarks as to how this project provides additional evidence toward the affirmative.

CHAPTER 2: LUNISOLAR PHENOMENA AND EARLY GREEK LUNISOLAR CYCLES

The Moon travels around the Earth in a near circular orbit, completing one revolution in an average period of 27.32 days. This is known as a *sidereal month*. Of course, the Earth is also traveling around the Sun, completing a revolution after 365.26 days, known as a *sidereal year*. Because the Earth is speeding along its orbit around the Sun, it takes the Moon just over two additional days to return to its initial alignment with the Earth and Sun for a total of 29.53 days, called a *synodic month* or *lunation*.

When the aforementioned alignment or *syzygy* is in the order of Earth-Moon-Sun, the moon is completely dark, also known as a new moon or *conjunction*. When the syzygy is Moon-Earth-Sun, the entire disk of the Moon is illuminated in what is called a full moon or *opposition*. New moons and full moons present two of the four principal lunar phases, the other two known as first quarter and last quarter. Moreover, there are approximately 7.28 days between each principal phase, with the new moon recognized in ancient Babylonia as the final phase within each lunation.[18] Figure 1 illustrates each principal phase and its approximate day of occurrence in the synodic month.

One can quickly surmise that the seven-day week has its origins with the interval between each principal lunar phase. In various Babylonian and Assyrian calendars, days

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[18] In western culture, four intermediate lunar phases are also recognized: waxing crescent (right side of lunar disk illuminated 1-49%), waxing gibbous (right side of lunar disk illuminated 51-99%), waning gibbous (left side of lunar disk illuminated 51-99%), waning crescent (left side of lunar disk illuminated 1-49%). From the fifth tablet of the Babylonian creation epic, the *Enūma Eliš* (ca. 18th century BCE), we know that the lunar month was considered by Babylonians to start at the beginning of the waxing crescent.

7, 14, 21, and 28 from the new moon were called *uhulgallū* and regarded as "evil" or unfavorable days.[19] Consequently, certain activities were prohibited to avoid ill consequences. The king was not to eat cooked meat or baked bread, to ride out in his chariot, or to issue any decrees. Priests were not to deliver oracles, and doctors did not treat the sick.[20] Therefore, it appears that evil portents were associated with all principal lunar phases and not just lunar eclipses.

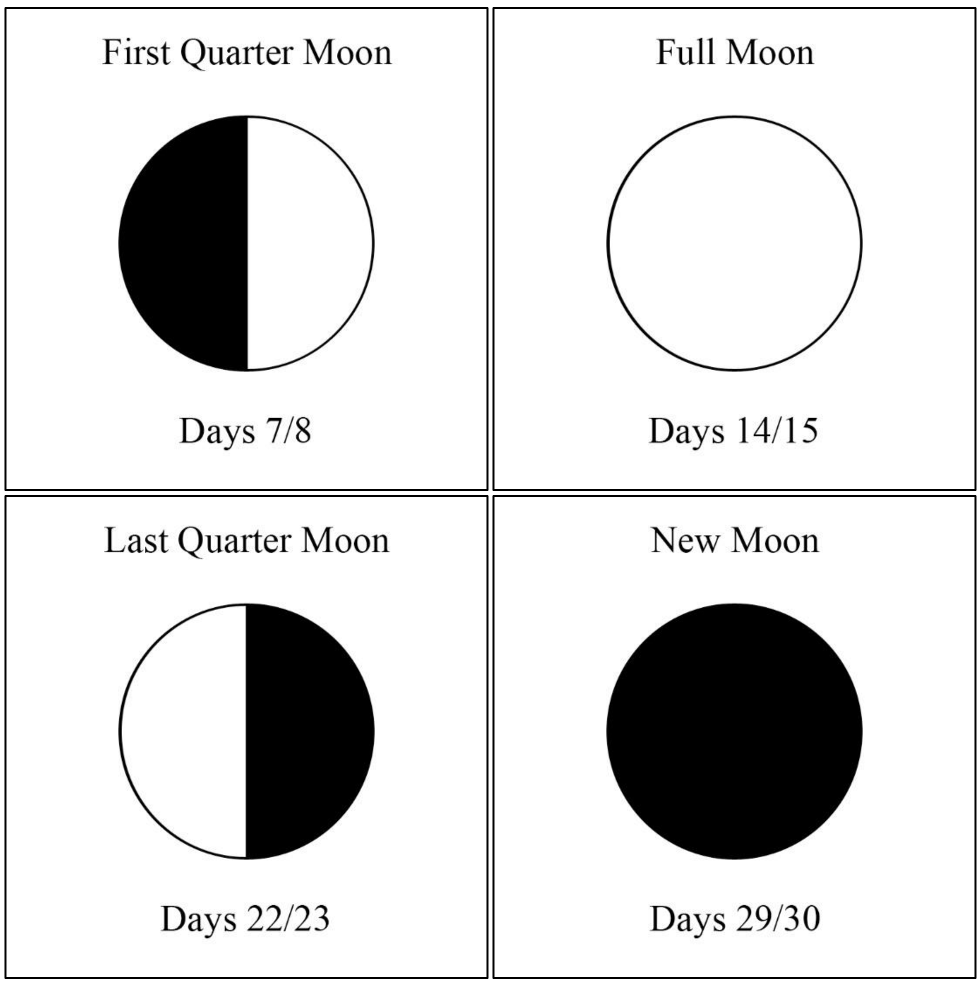

FIGURE 1: Principal lunar phases in a synodic month

[19] Rochberg-Halton, *ABCD*, 38.

[20] Roland de Vaux, *Ancient Israel: Its Life and Institutions*, trans. John McHugh (1961; repr., Grand Rapids, MI: William B. Eerdmans Publishing Co., 1997), 476.

2.1. Lunar Eclipses

The apodoses related to lunar eclipses in omen texts provided some of the most ill-fated portents that can be directed against a king or the land. Each quadrant of the lunar disk corresponded to one of the four quarters of the known world (Amurru, Elam, Subartu/Assyria, Akkad/Babylonia). An eclipse over one or more quadrants portended a threat to the corresponding regions whereas a total lunar eclipse signified danger for all kings of the world. To avert potential calamity, celestial diviners were on constant alert to prepare specific protection rites in advance. The most notable of these was the “substitute king ritual” in which an unfortunate individual, usually a prisoner or criminal sentenced to death, was selected to “rule” temporarily for up to 100 days in the king’s place (depending on the magnitude of the eclipse) to absorb any perceived evil that was portended against the king. The individual was then executed so that the evil was carried with him into the netherworld.[21] As a result, considerable attention was placed on being able to predict lunar eclipses (and other planetary) occurrences so that a substitute king could be installed beforehand.

From our perspective on Earth, the Sun appears to be moving along a path in the observable sky known as the *ecliptic*. The Moon’s path as viewed from Earth intersects the ecliptic twice during the sidereal month at points called *nodes*; and the average interval it takes for the Moon to return to the same node is 27.21 days called a *draconic month*. Eclipses can only occur when the Moon is near one of these nodes (every 13.6 days) and in syzygy. If the Moon is near a node during a new moon (conjunction), the Moon casts a shadow on the earth’s surface, partially or totally obscuring the Sun in a

[21] Parpola, *LAS*, vol. 2, xxii-xxv.

solar eclipse. Accordingly, if a full moon (opposition) is close to a node, the Earth casts a shadow on the Moon, partially or totally obscuring the Moon in a lunar eclipse. The magnitude of an eclipse, defined as the fraction of the diameter of the eclipsed body that is shadowed, is determined not only by the Moon's path but also its distance from the Earth because of its elliptical orbit. The point where the Moon is closest to the Earth is known as the *perigee*, and the interval from perigee to perigee is 27.56 days called an *anomalistic month*.

Within ancient Near Eastern studies, scholars such as Otto Neugebauer have long acknowledged that the Babylonians were aware of lunar eclipses occurring in six-month and occasionally five-month intervals. Yet, there has always been doubt as to whether this knowledge developed into a mathematical theory prior to the fifth century BCE.[22] Lunar eclipses are visible anywhere on the Earth when the Moon is above the horizon; so it is fairly easy to detect cycles of occurrence over time. The *Saros* period in which 38 lunar eclipse possibilities occur within a timeframe of 223 synodic months is thought to be such a cycle. The Babylonians referred to this period as "18 MU.MEŠ" (18 years) because of its closeness to 18 sidereal years. Moreover, 223 synodic months are very close in days to 242 draconic months and 239 anomalistic months, resulting in an eclipse recurring with a similar magnitude and duration every 18 years.[23]

From eclipse observations and basic algebra, one can deduce that 33 of the 38 lunar eclipse possibilities occur after six-month intervals, with the remaining five

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[22] O. Neugebauer, *The Exact Sciences in Antiquity* (New York: Dover Publications, 1969), 101-102.

[23] 223 synodic months ≈ 18.03 sidereal years ≈ 6585.413 days; 242 draconic months ≈ 6585.304 days; and 239 anomalistic months ≈ 6585.645 days.

possibilities occurring after intervals of five months.[24] John M. Steele proposes that by distributing the five-month eclipse intervals evenly throughout the Saros cycle, the 38 eclipse possibilities can be divided into five groups of eight, seven, eight, seven, and eight occurrences respectively (8-7-8-7-8). The Astronomical Diaries provide numerous examples of five-month interval eclipses, which are notated with the logogram "5 ITU" after the month of occurrence; and potential evidence from tablet BM 38462 (*LBAT* *1420) suggests that Babylonian astrologers could have been using the 8-7-8-7-8 Saros distribution scheme to predict lunar eclipses as early as 575 BCE. In addition, Steele and Lis Brack-Bernsen note that the structure of the scheme appears to be present in recordings that include the 6 February 747 BCE lunar eclipse:

> 1,40 MU SAG NAM-LUGAL-LA [x x x]
> ŠE 5 ITU 14 U$_4$-ZAL GAR *ád* ⸢x⸣ [x x]
> 2,10 MU-1 KIN [1] ⸢5?⸣ GAR *ina* SI SAR [x (x)]
> [x] ULÙ ⸢GIN⸣ *ád* ŠÚ KIN D[IR]
>
> 1,40. Accession year [of …]
> Month XII, (after) 5 months, the 14th, morning watch, it made (an eclipse)? …
> […]
> 2,10. Year 1. Month VI, [the 1]⸢5th?⸣, it made (an eclipse)? It began in the north
> […]
> […] the south wind blew. It set eclipsed. Month VI was in[tercalary.][25]

However, Steele and Brack-Bernsen also admit the possibility of the scheme being projected back upon these observations in later recensions.[26] Backward projection of the Saros scheme appears to be the most probable scenario, particularly when one

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[24] Within a 223 month period, x eclipses occur after six months and y eclipses occur after five months for the equation of $6x + 5y = 223$. From eclipse observations, six-month eclipse intervals are more than five times likely than five-month eclipse intervals, resulting in $x > 5y$. The only solution for these two equations is $x = 33$ and $y = 5$.

[25] BM 41985 (*LBAT* 1413), Obv.', lines 1-4; trans. Hunger, *Astronomical Diaries,* 3. The eclipses referenced are thought to date to ones occurring on 6 February 747 and 2 August 747 BCE respectively.

[26] Lis Brack-Bernsen and John M. Steele, "Eclipse Prediction and the Length of the Saros in Babylonian Astronomy," *Centaurus* 47, no. 3 (September 2005), 182.

considers that many of the 38 eclipse possibilities in each Saros would not have been visible from Mesopotamia. Appendix A contains a table that compares the 8-7-8-7-8 distribution over two Saros periods (747-711 BCE) against actual occurrences of five-month interval eclipses (rows highlighted in bold) as well as a distribution of occurrences that would have been observable to astrologers. Saros series eclipse numbers are listed for each of these three distributions in table 1 below:

TABLE 1: Summary of Saros five-month interval lunar eclipse distributions (747-711 bce)

	Saros Series Numbers of Five-Month Interval Eclipses		
Lunar Eclipse Date	Actual	8-7-8-7-8 Scheme	Observable Scheme
-746 Feb. 6	1	1	1
	8	9	9
	15	16	16
	22	24	24
	30	31	31
	37	1	4
	8	9	10
	15	16	18
	22	24	24
	30	31	32
-710 Feb. 27	1	1	1

Note: Eclipse dates are expressed in astronomical year numbering in which the year 0 = 1 BCE, −1 = 2 BCE, etc.

The 8-7-8-7-8 and observable distributions each successfully predict only one actual occurrence of a five-month interval eclipse over a 36-year period, both of which happen to be the first eclipse of the third Saros period. Coincidentally or perhaps as initially derived by Steele, both schemes predict the exact same distribution of lunar eclipse numbers 1, 9, 16, 24, and 31 for the first Saros period. When we compare predictions from these two schemes in the second Saros period, however, we begin to see numerous and sometimes wide discrepancies. The 8-7-8-7-8 scheme predicts the same series of eclipse numbers in the second Saros by design; and with the exception of the first eclipse, discrepancies between its distribution and actual occurrences remain consistent. In the observable distribution, eclipse visibility (or lack thereof) obscures patterns of eclipse occurrence. For example, the lunar eclipses of 2 August 747 and 12 August 729 BCE both occur second within their respective Saros series as listed in appendix A. As a result, they are similar in magnitude, having the appearance of total or near-total eclipses. Yet, the 12 August 729 BCE eclipse was only visible from the Pacific Ocean; so from the perspective of Babylonian astrologers, this eclipse did not occur. More importantly, appendix A shows multiple stretches of four to five consecutive eclipses that would not have been visible from Mesopotamia, many of which include five-month interval eclipses. Therefore, astrologers could only assume that each “missing” eclipse occurred six months after the previous one until the next visible eclipse indicated otherwise by appearing one month early.

Steele states that the 8-7-8-7-8 sequence is arbitrary and that the distribution scheme could be any permutation of sevens or eights (e.g. 7-8-7-8-8 or 8-7-8-8-7) depending on when the start of a Saros period is defined.[27] Nevertheless, the distribution of actual occurrences is 7-7-7-8-7 followed by 9-7-7-8-9 while the observable distribution is 8-7-8-7-11 followed by 6-8-6-8-7, none of which are permissible in permutations of Steele’s schemes and of which the interval numbers in each sequence of the latter can potentially change due to lack of visibility. Consequently, as a predictive tool, the 8-7-8-7-8 Saros scheme would be no more accurate or verifiable than counting the number of days since the last eclipse. The average time between each eclipse is 177 days (six months of 29.53 days), with a few eclipses occurring after 148 days (five months of 29.53 days) as illustrated in appendix A. Furthermore, letters to Assyrian kings

[27] John M. Steele, *Observations and Predictions of Eclipse Times by Early Astronomers* (Dordrecht, The Netherlands: Kluwer Academic Publishers, 2000), 79n108.

indicate that astrologers were interested in predicting eclipse occurrences to the actual day:

> As regards the watch of the Sun about which the king, my lord, wrote to me, it is (indeed) the month for the watch of the Sun. We keep its watch twice, on the 26th of Araḫsamna (and) the 26th of Kislimu. In this way we keep the watch of the Sun for 2 months.
>
> As regards the solar eclipse about which the king spoke, the eclipse did not occur. I shall look again on the 27th (and) write (to the king).
>
> The king, my lord, must have (already) discharged me! In deep anxiety, I have nothing to report.[28]

The above inscription highlights the stress ancient astrologers experienced while attempting to predict eclipses accurately. Notice that the solar eclipse was expected to occur on the 26th of *Araḫsamna* (Month VIII) or *Kislīmu* (Month IX) as opposed to the 29/30th of these months when the moon is in conjunction. This suggests that astrologers would have to accommodate various calendar schemes with variable month lengths and insertions of intercalary months. The only way for them to predict eclipses (lunar or solar) to the actual day would be to maintain or to calculate a count of 148 or 177 days. Therefore, the use of Saros distributions as proposed by Steele and Brack-Bernsen, if in fact used at all, would best serve as retrospective approximations of five-month interval eclipses that scribes would use to uncover patterns within large sets of previously recorded observations.

2.2. Early Greek Lunisolar Cycles

Although the Saros does not appear to have been used to predict eclipses prior to the sixth century BCE, John P. Britton argues that knowledge of the 18-year period may

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[28] *ABL* 687; trans. Parpola, *LAS*, vol. 1, 29. Parpola dates this inscription to 2 December 670 BCE. A solar eclipse did occur on this date but was not visible from Mesopotamia. For commentary, see Parpola, *LAS*, vol. 2, 51.

have led to the discovery of the 19-year lunisolar cycle. The length of the lunar year is on average 354.37 days (12 x 29.53 days), which is 10.87 days shorter than the average tropical (solar) year of 365.24 days. For this reason, the goal of a lunisolar calendar is to reconcile this difference in days, known as the *epact*, so that lunar calendar months remain consistent with solar seasons primarily for agricultural purposes. The inscriptional texts provide evidence for several strategies that were used to synchronize lunar and solar years, namely the insertion of 30-day intercalary months every 2.5 to 3 years. Small discrepancies often remain after the insertion of an intercalary month, so scribes would need to recognize certain lunisolar cycles to know when the lunar and solar years were once again in sync.

One such lunisolar cycle occurs after 19 solar years (6,939.60 days), which is nearly equal to 235 synodic months (6,939.69 days). The Greek astronomer Meton of Athens is credited with introducing the 19-year cycle around 432 BCE; yet, evidence of the cycle's use can be detected starting from the reign of Darius I (522 BCE).[29] This "Metonic" cycle requires the insertion of seven 30-day intercalary months in years 3, 6, 8, 11, 14, 17, and 19. As shown in table 2, intercalary months are inserted in the cycle to prevent the epact from exceeding 30 days.

The origins of the 19-year cycle are even a greater mystery, with hypotheses ranging from the mathematical to the haphazard. It has long been suspected that this cycle was derived from the less accurate 8-year cycle, popularly known as the *octaeteris*. Eight solar years (2,921.94 days) equates approximately to 99 synodic months (2,923.53 days); therefore, the *octaeteris* requires the insertion of three 30-day intercalary months

[29] Stern, *Calendars in Antiquity*, 105.

TABLE 2: Schematic calendar for 19-year cycle

Cycle Year	Intercalary Month	Year Length (Days)	Total Lunar Days	Total Solar Days	Epact (Days)
1		354	354	365.25	-11.25
2		354	708	730.5	-22.5
3	XII	384	1092	1095.75	-3.75
4		354	1446	1461	-15
5		354	1800	1826.25	-26.25
6	XII	384	2184	2191.5	-7.5
7		354	2538	2556.75	-18.75
8	XII	384	2922	2922	0
9		354	3276	3287.25	-11.25
10		354	3630	3652.5	-22.5
11	XII	384	4014	4017.75	-3.75
12		354	4368	4383	-15
13		354	4722	4748.25	-26.25
14	XII	384	5106	5113.5	-7.5
15		354	5460	5478.75	-18.75
16		354	5814	5844	-30
17	XII	384	6198	6209.25	-11.25
18		354	6552	6574.5	-22.5
19	XII	384	6936	6939.75	-3.75

in years 3, 5, and 8 or possibly 3, 6, and 8 of the cycle (5 x 354 days + 3 x 384 days = 2,922 days).[30] Remnants of the 8-year cycle can be seen in table 2, with intercalary months in years 8 and potentially 16 removing mathematic discrepancies between lunar and solar years. Writing in the third century CE, Censorinus reports that the invention of the 8-year cycle was attributed to Kleostratos towards the end of the sixth century BCE.[31] However, Robert Hannah, using George Thomson’s long-held argument that the cycle

[30] Ancient societies would be fully aware of simple-fractional days and know that the eight-year cycle would be 99 synodic months or 2,920.5 days (99 x 29.5 days), resulting in a deficit of 1.5 days from their perspective even though there would actually be a surplus of 1.633 days. However, the rounding associated with alternating month lengths between 29 and 30 days mitigates this discrepancy. The years of intercalation are according to Geminos, *Introduction to Astronomy* 8.33; cited by Robert Hannah, “Early Greek Lunisolar Cycles: The Pythian and Olympic Games,” in *Living the Lunar Calendar*, ed. Jonathan Ben-Dov, Wayne Horowitz, and John M. Steele (Oxford: Oxbow Books, 2012), 80.

[31] Censorinus, *On the Birthday* 18.6; cited by Hannah, “Early Greek Lunisolar Cycles,” 79.

existed beforehand in various forms, argues that the *octaeteris* could have been used in Olympia as early as the eighth century BCE.[32] Unfortunately, the use of the *octaeteris* alone does not provide an astronomical foundation for either lunisolar cycle.

Britton proposes that it was the study of eclipses that led to the introduction of the 19-year cycle, noting that Babylonian astrologers could have easily discovered that "eclipses separated by 235 synodic months recur in the same place in the sky" to form a 19-year lunistellar cycle.[33] One also cannot discount the potential early role of equinoxes and solstices in uncovering the cycle as evidenced by a text from Uruk (W22801) in which dates for summer and winter solstices are listed schematically in 19-year intervals from 626 to 531 BCE.[34] Moreover, the MUL.APIN contains two intercalation schemes, one in which the risings of the Sun, visibility of the Moon, and the constellations are used to determine equinoxes, solstices, and the need for intercalary months. Nevertheless, critics contend that the above proposals rely on a flawed assumption that the 19-year cycle was a scientific discovery resulting from advances in Babylonian mathematical astronomy and the need for intercalations.[35] According to Sacha Stern, "[t]he relationship between calendar regulation and astronomy has generally been overstated. It is certainly absurd to argue, as many have done, that the development of Babylonian astronomy itself was motivated by an urge to regulate the calendar: indeed, planetary and stellar astronomy, which dominate Babylonian astronomy, have no relevance to the lunar

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[32] Hannah, "Early Greek Lunisolar Cycles," 79.

[33] John P. Britton, "Calendars, Intercalations and Year-Lengths in Mesopotamian Astronomy," in *Calendars and Years: Astronomy and Time in the Ancient Near East*, ed. John M. Steele (Oxford: Oxbow Books, 2010), 127.

[34] Ibid., 125.

[35] Stern, *Calendars in Antiquity*, 115-117.

calendar."[36] In addition, he sees equinoxes and solstices as providing no astronomical rationale to the Babylonian 19-year cycle, attributing the latter to trial and error on the part of astrologers with minor use of mathematical astronomy.[37]

Although I agree with Stern that the paradigm of calendar regulation depending on advances in mathematical astronomy is problematic, I argue that the 19-year lunisolar cycle was indeed a scientific discovery of Babylonian astrologers who observed period relations between lunar phases, equinoxes, and solstices. Tables 3-4 illustrate these patterns by showing new and full moons occurring on the same evening (or within the same 24-hour period) as the vernal equinox or the summer solstice respectively every 19 years. This 19-year cycle exists for any lunar phase and equinox/solstice combination.

TABLE 3: 19-year lunar phase/equinox cycle example

New Moon		Vernal Equinox			
Date	Time (UT)	Date	Time (UT)	Difference (Days)	Interval (Years)
-733 Mar. 29	01:34	-733 Mar. 29	01:59	-0.017	
-725 Mar. 30	15:20	-725 Mar. 29	00:01	1.627	8
-714 Mar. 28	10:20	-714 Mar. 28	16:29	-0.256	11
-695 Mar. 27	18:28	-695 Mar. 28	07:01	-0.523	19
-687 Mar. 29	12:37	-687 Mar. 28	05:25	1.300	8
-676 Mar. 27	09:07	-676 Mar. 27	21:27	-0.514	11
-668 Mar. 28	22:05	-668 Mar. 27	19:50	1.094	8
-657 Mar. 28	07:06	-657 Mar. 28	11:47	-0.195	11
-649 Mar. 29	15:24	-649 Mar. 28	10:00	1.225	8
-638 Mar. 28	07:50	-638 Mar. 28	02:03	0.240	11
-630 Mar. 29	14:49	-630 Mar. 28	00:01	1.598	8
-619 Mar. 28	05:45	-619 Mar. 27	16:35	0.549	11
-611 Mar. 29	15:11	-611 Mar. 27	14:52	2.013	8
-600 Mar. 27	20:51	-600 Mar. 27	07:22	0.561	11
-581 Mar. 28	04:39	-581 Mar. 27	21:49	0.285	19
-562 Mar. 27	13:35	-562 Mar. 27	12:13	0.057	19
-543 Mar. 27	06:10	-543 Mar. 27	02:33	0.151	19
-524 Mar. 27	05:16	-524 Mar. 26	17:02	0.510	19

Note: For tables 3-4, eclipse dates are expressed in astronomical year numbering in which the year 0 = 1 BCE, −1 = 2 BCE, etc. Julian dates for astronomical phenomena are calculated using algorithms from Meeus and Delta T (ΔT) adjustments from Morrision and Stephenson.

[36] Ibid., 119.

[37] Ibid. 118-119.

TABLE 4: 19-year lunar phase/solstice cycle example

Full Moon		Summer Solstice			
Date	Time (UT)	Date	Time (UT)	Difference (Days)	Interval (Years)
-743 June 30	01:35	-743 June 30	20:35	-0.791	
-735 July 1	19:52	-735 June 30	19:19	1.023	8
-724 June 29	09:30	-724 June 30	10:57	-1.060	11
-716 July 1	03:21	-716 June 30	09:33	0.742	8
-705 June 30	00:01	-705 July 1	01:07	-1.035	11
-697 July 1	13:13	-697 July 1	00:00	0.547	8
-686 June 29	22:36	-686 June 30	15:40	-0.711	11
-678 July 1	06:43	-678 June 30	14:14	0.686	8
-667 June 29	23:16	-667 June 30	05:56	-0.277	11
-659 July 1	06:16	-659 June 30	04:27	1.076	8
-648 June 29	21:02	-648 June 29	20:12	0.035	11
-640 July 1	06:38	-640 June 29	18:52	1.490	8
-629 June 30	11:25	-629 June 30	10:34	0.035	11
-610 June 29	19:11	-610 June 30	00:02	-0.232	19
-591 June 29	04:39	-591 June 29	15:38	-0.458	19
-572 June 28	21:09	-572 June 29	05:60	-0.369	19
-553 June 29	20:07	-553 June 29	20:12	-0.003	19
-534 June 29	20:32	-534 June 29	10:27	0.421	19

The *octaeteris* and 11-year cycle also may have originated from these observed patterns as shown in the tables below, but each sub-cycle is individually less accurate than when combined to form the 19-year cycle. For example, in the case of the 8-year cycle, the new moon occurs 1.627 days after the equinox; and this discrepancy only increases after successive reiterations of the cycle. In chapter 4, however, I will discuss how adding an extra day to a 29- day month 3 times over 2 cycles can mitigate this discrepancy to make the 8-year cycle viable as a basis for Old Babylonian period calendars. Nevertheless, if the 19-year cycle can be attributed to observations of lunar phases rather than mathematical astronomy, then it is quite possible that the cycle was in use much earlier than previously thought. This opens the potential of intercalation being determined by cardinal phenomena in respect to lunar phases of certain calendar months rather than arithmetic epacts within a cycle. To support these new hypotheses, we will need to determine if and when Babylonian astrologers had developed technology to detect equinoxes and solstices within acceptable margins of error.

2.3. Summary

The four principal lunar phases served a pivotal function in ancient Babylonian calendrics and celestial divination; for not only were they likely the basis of the seven-day week but were also perceived as ominous signs by astrologers. Individuals tasked with protecting the king and the empire were particularly concerned about lunar eclipses, developing rudimentary methods of prediction so as to prepare protection rituals in advance. As a result, modern scholars, such as Britton, have proposed that this Babylonian concern over eclipse occurrences is in fact what led to the discovery of the 18-year Saros cycle and eventually the 19-year lunisolar cycle, the latter becoming essential in the development of the calendar.

Although the MUL.APIN contains evidence that the determination of cardinal phenomena was also linked to determining the need for intercalary months, equinoxes and solstices are often viewed today as providing no astronomical basis for the Babylonian 19-year cycle. However, period relations between cardinal phenomena and the principal lunar phases naturally do occur in cycles of 19 years, with potential sub-cycles of 8 or 11 years. Therefore, it is quite possible that new and full moons observed in relation to equinoxes and solstices provided Babylonian astrologers with a systematic but non-arithmetic method for inserting extra months into the calendar year before the start of the first millennium BCE.

CHAPTER 3: THE BABYLONIAN WATER CLOCK

The observation that days are longer in the summer than they are in the winter is probably as early as humans have inhabited the Northern Hemisphere. Administrative texts of the pre-Sargonic period (ca. 2500-2350 BCE) demonstrate that Mesopotamian scribal culture was already using a 360-day schematic calendar of twelve 30-day months to facilitate calculations. Sowing and harvest festivals are attested throughout this scheme during the Ur III period (ca. 2100 BCE), indicating that the latter was structured around the agricultural seasons. By the Old Babylonian period (ca. 1800-1600 BCE), solstices and equinoxes are arranged equidistantly on the 15th of months III, VI, IX, and XII of the 360-day calendar to form an "ideal year" as evidenced by Tablet 14 of the *Enūma Anu Enlil*.[38] The Old Babylonian text BM 17175+17284 provides the earliest explicit description of this scheme and assigns the values of 2, 3, 4, and 3 to the night watches of the solstice and equinox schematic dates above.[39] These values are listed with no units of measure and no indications of what they supposedly quantify; however, it is quite clear from Table C of Tablet 14 that these values represent weights in units known as *minas* corresponding to the duration of darkness on the nights of cardinal phenomena.[40] Combining the information of Tablet 14 and BM 17175+172184 recreates the "ideal

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[38] Lis Brack-Bersen, "The 360-Day Year in Mesopotamia," in *Calendars and Years: Astronomy and Time in the Ancient Near East*, ed. John M. Steele (Oxford: Oxbow Books, 2010), 83-97.

[39] Hunger and Pingree, *MUL.APIN*, 163-164.

[40] F. N. H. Al-Rawi and A. R. George, "Enūma Anu Enlil XIV and Other Early Astronomical Tables," *Archiv für Orientforschung*, Bd. 38/39 (1991/1992): 57.

year" scheme shown in table 5. In addition, three important facts of the Old Babylonian period can be inferred from these two texts: (1) a device that measured lengths of day and night was in existence; (2) Babylonian astrologers possessed the ability to detect equinoxes and solstices; and (3) the astrologers were using a ratio of 2:1 for the longest to the shortest night of the winter and summer solstices.

TABLE 5: Old Babylonian "ideal year" scheme

Solar Event	Date	Day Watch	Night Watch
Summer Solstice	Month III – 15 *Simānu*	4 *minas*	2 *minas*
Autumnal Equinox	Month VI – 15 *Ulūlu*	3 *minas*	3 *minas*
Winter Solstice	Month IX – 15 *Kislīmu*	2 *minas*	4 *minas*
Vernal Equinox	Month XII – 15 *Addaru*	3 *minas*	3 *minas*

3.1. Theoretical Specifications of the Water Clock

Although we find no schematic description of the water clock within the inscriptional corpus, Old Babylonian mathematical texts provide philological clues as to how the clock may have functioned. These texts make reference to a device called a $^{\mathbf{gi\check{s}}}$**dib-dib** in Sumerian (*dibdibbu* in Akkadian) out of which poured a substance that was probably water but possibly also sand. The Standard Babylonian lexical series Ur$_5$-ra IV 6-10, dating to the first millennium BCE, equates $^{\mathbf{gi\check{s}}}$**dib-dib** to several useful terms as well, namely the word *muzibbu* in Ur$_5$-ra IV: 7, a possible derivation of the word *zâbu* which connotes "dripping." This suggests that $^{\mathbf{gi\check{s}}}$**dib-dib** may also be onomatopoeic, perhaps reflecting water dripping slowly out of the device. However, Ur$_5$-ra IV: 8 uses the word *mušiḫḫu*, meaning "that which grows/increases," indicating that water may have been dripping into some measuring device. Via the term *maštaktum*, $^{\mathbf{gi\check{s}}}$**dib-dib** is indirectly linked to another device called a $^{\mathbf{gi\check{s}}}$**ki.lá**, which relates to the Akkadian word *kalakku* that can mean "vessel." Since **ki.lá** refers to "weight" or "the act of weighing," the ^{giš}**dib-dib** may have been understood as a wooden (**giš**) device that weighed water. Thus, from the philological evidence, we can construct a general description of the water clock as a wooden device that measured time corresponding to the weight of water (measured in *minas*) that slowly dripped into or out of the device.[41]

3.1.1. Neugebauer's Water Clock

Neugebauer's early work on the water clock has been pivotal in later interpretations of Old Babylonian time measurements because it incorporated F. X. Kugler's earlier observation that these recordings were written in units of weight rather than units of time. Moreover, it attempts to reconcile the Babylonian 2:1 ratio of longest night to shortest night with an equally simple 3:2 ratio that is much closer to what is observed in nature. Decades prior to Neugebauer, E. F. Weidner and L. W. King note that both ratios are found in the MUL.APIN. Weidner, in particular, makes reference to the second tablet of the MUL.APIN in which Babylonian astrologers demonstrated awareness of the 3:2 ratio from their use of sundials to compare the longest and shortest days. Thus, astrologers would have easily deduced that this ratio could apply to the longest and shortest nights as well. The 2:1 ratio nevertheless continues to be used for the longest and shortest nights as inferred from tablet BM 86378.[42]

Using conservation of energy and Bernoulli laws in which the potential energy of water stored in a vessel equals the kinetic energy of it flowing out, Neugebauer reasons that the time t needed for water of height h to completely flow out of a vessel is dictated

[41] David Brown, John Fermor, and Christopher Walker, "The Water Clock in Mesopotamia," *Archiv für Orientforschung*, Bd. 46/47 (1999/2000): 132-133.

[42] O. Neugebauer, "The Water Clock in Babylonian Astronomy," *Isis* 37, no. 1/2 (May, 1947): 38-39.

by the formula $t = c\sqrt{h}$, where c is a constant depending on the outlet and the cross-sectional area of the vessel. Since the weight *w* of the water contained in the vessel is proportional to *h*, the ratio between two different time intervals of *T* and *t* equals the ratio of the square roots of the corresponding weights of water *W* and *w* (i.e. $: t = \sqrt{W} : \sqrt{w}$). In other words, the 3:2 ratio corresponds to a water weight ratio of 9:4. Neugebauer argues that the Babylonians approximated this latter ratio to 8:4, resulting in the 2:1 ratio inferred from inscriptions. From the *Enūma Anu Enlil*, we know that day and night were divided into three watches each. Neugebauer interprets the day watch and night watch values in the Old Babylonian "ideal year" scheme above as being applied to each of the three watches. On the summer solstice, for example, 12 *minas* would be measured for the entire day watch and 6 *minas* for the entire night watch, with an approximate ratio of 3:2 (i.e. $\frac{3\ x\ \sqrt{4}}{3\ x\ \sqrt{2}} = \frac{2}{\sqrt{2}} \approx 1.414$). With these assumptions, Neugebauer concludes that the water clock consisted of a cylindrical clepsydra with an outlet at its bottom from which a specified amount of water was expected to drain during each watch.[43]

Modern scholarship, however, has uncovered numerous problems with Neugebauer's model. As stated earlier, Tablet 14 and the MUL.APIN confirm the use of weights to measure time; but other parts of both texts suggest that astrologers perceived a proportional rather than square root relationship between daylight and darkness. This fact is made explicit in Late Babylonian period texts such as BM 29371.[44] Therefore, while it is possible for the structure of the water clock to have changed over the centuries, it is highly unlikely that the mathematical basis for the device would have changed as well,

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[43] Ibid., 39-40.

[44] Brown, Fermor, and Walker, "The Water Clock in Mesopotamia," 141.

particularly since a sexagesimal numeral system poorly handles the fractions that many square root calculations would introduce.

A second problem is whether or not water from the clock could drip slow enough so as not to be emptied before the end of the watch. Some researchers interpret the weight values in the "ideal year" scheme as corresponding to an entire day or night instead of a watch as proposed by Neugebauer.[45] A *mina* of water weighs approximately 0.5 kg, which translates in volume to 0.5 liters.[46] Thus, whether one interprets 3 *minas* or 1.5 liters (in the case of an equinox) as dripping for either 4 hours or 12 hours, an outlet with a very tiny bore is required to achieve such slow discharge rates.

The requirement of a tiny outlet forces us to recognize issues of *viscosity* and *capillarity* concerning the clock's design. Viscosity in the context of this study is the resistance of a liquid substance to flow (e.g. molasses has a higher viscosity than water). This resistance increases as temperature decreases. In the case of the water clock, flow consistency, which is assumed under Bernoulli law, begins to break down if the flow rate is too slow or too fast due to (1) the increased friction of squeezing through a tiny opening and/or increased viscosity during colder seasons and (2) the resulting turbulence caused by decreased viscosity during hotter seasons. In other words, Bernoulli law is only applicable at around 20°C or room temperature.

A tiny opening also allows a liquid substance to take advantage of capillarity, which is the use of surface tension to counteract the force of gravity. A thin film of water, for example, will stick to surfaces and will require more energy to move the thinner the film becomes. The corresponding capillary pressure from the surface tension will oppose

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[45] Al-Rawi and George, "Enūma Anu Enlil XIV," 59-60.

[46] M. A. Powell, "Mass und Gewichte," *Reallexikon der Assyriologie* 7 (1987-1990): 510.

the hydrostatic pressure from the water's weight. As the water level lowers, these two pressures will eventually reach equilibrium, causing flow to end with a residual layer of water at the bottom of the vessel. The height h_c of this residual layer is determined by the formula $h_c = \frac{2\lambda^2}{\phi}$ where λ is the "capillary length" (≈ 0.27 cm for water) and ϕ is the diameter of the opening.[47] For a diameter of 1.5 mm, a fairly "large" opening within the context of this study, h_c equals almost a full centimeter. A residual layer of water this high would have certainly been noticed by the Babylonians and eliminates any model that requires water in the clock to discharge completely.

3.1.2. Experimental Results

It is clear that numerous physical laws and variables factor into the functionality of the water clock; therefore, experimentation is needed to eliminate nonviable parameters and to explore the water clock's actual capabilities. Stephenson *et al.* lead this effort by contributing two very important findings related to lunar eclipse times. First, they find no evidence that the device slowed down during watches when used to measure phase intervals of eclipses, meaning that the water's height in the vessel was kept at a constant level or *head* to achieve a constant flow.[48] Second, they find no seasonal variation of accuracy in measurements for eclipse records spanning over 500 years.[49] Both of these findings thus strongly suggest that the design of the water clock effectively resolved issues of viscosity and capillarity.

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[47] For detailed discussion concerning the issues of viscosity and capillarity, see also C. Michel-Nozières, "Second Millennium Babylonian Water Clocks: a physical study," *Centaurus* 42 (2000): 184-199.

[48] F. R. Stephenson and L. J. Fatoohi, "Lunar Eclipse Times Recorded in Babylonian History," *Journal for the History of Astronomy* 24, no. 4 (1993): 260-61.

[49] 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, no. 4 (1997): 343.

Brown *et al*. hypothesize that the clock was kept inside a building to shield it from extreme temperatures that would affect the viscosity of water in the device.[50] Fermor and Steele acknowledge that enclosing the device within a structure would not be sufficient to eliminate seasonal effects entirely, so they also introduce the possibility of the water clock having a short spout to mitigate temperature effects. Even if we assume an annual indoor-temperature range of 10-30°C, the viscosity of water can increase by up to 64%, thereby decreasing the flow rate by as much as 56%. However, tests of various spout lengths by Fermor and Steele reveal that a spout 1.5 cm in length would reduce the flow rate discrepancy down to 1.4%.[51]

Since water in the clock is kept at a constant head, presumably above the height when capillarity could stop water flow, the only problem left to solve is calibrating the clock to a desired flow rate. If we are correct in assuming that 3 *minas* or l.5 liters was expected to drip from the device during an entire watch or 4 hours on an equinox, then the required flow rate would equal 0.104 ml/s. One drop of water (gtt Metric) is equivalent to 0.05 ml. Therefore, the required flow rate would equal *two drops of water per second*—about the amount of time it takes to say **$^{\text{giš}}$dib-dib**.

Achieving a constant drip rate of two drops per second involves careful calibration between the bore diameter of the outlet and the head. Experiments by C. Michel-Nozières show that only a range of 0.9-1.3 mm for the bore diameter is permissible to generate repeatable results while avoiding issues of turbulence.[52] In

[50] Brown, Fermor, and Walker, “Water Clock in Mesopotamia,” 143.

[51] J. Fermor and J. M. Steele, “The design of Babylonian waterclocks: Astronomical and experimental evidence,” *Centaurus* 42, (2000): 217-18.

[52] Michel-Nozières, “Second Millennium Babylonian Water Clocks,” 188-195.

addition, Brown *et al.* argue that the Babylonians circumvented issues of capillarity by designing the water clock to have a large head. They propose a supply vessel to be of such size that the amount of water discharged into a smaller measuring vessel would be small enough to allow the head to remain near constant. Any discharged water would also be returned to the supply vessel at watch end to maintain water level.[53]

The incorporation of a large supply tank into the water clock's design is entertained via F. Thureau-Dangin's interpretation of two Old Babylonian mathematical texts (BM 85194 and BM 85210) containing four examples that explicitly mention the water clock (*dibdibbu*). Both texts contain examples such that (1) a variable a_o is provided, which is often interpreted as the full head for the device in units of **šu.si** or "fingers" (1 finger ≈ 1.67 cm); (2) a constant h_b is expressed as fraction of 10 fingers, which possibly represents the change in water level after a **sìla** (*qû*) of water (≈ 1 liter) flows out of the device; and (3) a fraction f is expressed that equals h_b/a_o. A value of 100 fingers for a_o is listed for all three examples found in BM 85194, leading Brown *et al.* to conclude that the device was large with an initial head of 167 cm (100 fingers x 1.67 cm).[54]

According to Michel-Nozières, however, an initial head of 167 cm would result in an accelerated flow rate that is turbulent and unsteady. Assuming a large bore diameter ϕ of 1.3 mm, the clock's maximum head of a_o would have to be less than 30 cm in order to avoid turbulence under the rule of $a_o\phi^2$<0.5 cm^3. A reinterpretation of the above mathematical texts by Thureau-Dangin in 1937 yields initial heads that are ten times

[53] Brown, Fermor, and Walker, "Water Clock in Mesopotamia," 137.

[54] Ibid., 134.

smaller, in line with this rule.[55] Because the constant h_b is recorded in the BM 85194 examples as a fraction of 10 fingers, it could be that initial heads are recorded as a fraction of 10 fingers as well for mathematical consistency. Yet, another possibility is that a_o refers not to the initial head but the cross-sectional area of the vessel, with the initial head understood to be 10 fingers as implied from constant h_b. The fraction f in each example would then equal the change in volume as a fraction of the total cubic volume under this new interpretation.[56] Either way, this translates to a revised initial head of 16.7 cm which becomes extremely attractive as we begin to think about the water clock's dimensions.

3.1.3. A Two-Stage Water Clock Design

The mathematical examples of BM 85194 and BM 85210 introduce an additional puzzle in that they suggest a water clock with a variable head in contradiction to the findings of Stephenson *et al.* Resolving this discrepancy requires reimagining the water clock as a two-stage system with the device consisting of a supply vessel at falling head, a dripping vessel at constant head, and a measuring vessel of rising head for reading time. Furthermore, prior designs of the water clock within recent scholarship have typically depicted the device as a clepsydra or earthenware vessel with an outflowing spout. These modern proposals, however, deviate from the Sumerian philological evidence. Therefore, the redesign of the water clock proposed in this study begins by returning to the notion of the **[giš]dib-dib** being a wooden (**giš**) device.

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[55] Michel-Nozières, "Second Millennium Babylonian Water Clocks," 186, 195.

[56] Brown, Fermor, and Walker, "Water Clock in Mesopotamia," 134. The f fractions for all four examples in this source can also be obtained via the formula $f = (\frac{x h_b}{\sqrt{a_o}} \times a_o)/a_o{}^{3/2}$ where x is the in/outflow in **sila** (*qû*).This formula implies f as a fraction of cubic volume.

Since an initial head of only 16.7 cm is required for the clock in general practice, it would not be difficult for a skilled craftsman to carve a box with an inner depth of at least this height from a single block of wood. If we imagine the inside of this box to have cubic dimensions, then it quickly becomes apparent that a height h_o of 10 fingers is by no means arbitrary. Such a device would contain 9.32 *minas* (≈ 4.66 liters) of water—an amount enough to last an entire day or night watch on an equinox in the “ideal year” scheme. Furthermore, bow-drills with thorn drilling bits are known to bore consistent holes of 1-3 mm in diameter, and such a tool could have been used to bore a hole of desired diameter in the floor of the box.[57] A tenth of a finger (≈ 1.7 mm) is probably the minimum length measured in general practice by ancient Babylonians as evidenced by constant h_b being expressed as a fraction of 10 fingers in the mathematical texts. However, the mathematical examples and the bow-drill archaeological evidence also suggest that the absolute minimum length capable of being measured (or at least approximated) during the Old Babylonian period was 0.05 fingers (≈ 0.9 mm). According to experiments by Michel-Nozières, the minimum bore diameter for repeatable results is 0.9 mm; and I propose this bore diameter for both the supply and dripping vessels in order to reduce water flow to the ideal rate of 0.104 ml/s as previously mentioned.[58]

When water flows from the supply vessel, it will be at a rate that is both variable and initially ten times faster than desired. As a result, a second dripping vessel is needed with an overflow mechanism to establish a constant head and flow. The final variable to determine, of course, is the constant head h_d that will allow water to drip at the desired

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[57] P. R. S. Moorey, *Ancient Mesopotamian Materials and Industries: The Archaeological Evidence* (Winona Lake, IN: Eisenbrauns, 1999), 107.

[58] Michel-Nozières, “Second Millennium Babylonian Water Clocks,” 195.

flow rate. The kinetic energy of the water is equal to the hydrostatic pressure at height h_d minus the capillary pressure from diameter ϕ. This relationship is represented by the formula $gh_d - \frac{2g\lambda^2}{\phi} = \frac{1}{2}v^2$ where g is the acceleration due to gravity (9.80 m/s^2) and v is the kinetic velocity. In addition, the kinetic velocity should equal our desired flow rate Q divided by the cross-sectional area of the outlet (i.e. $v = Q/\pi(\frac{\phi}{2})^2$). Solving for h_d yields for the dripping vessel a constant head of 1.76 cm or approximately 1.05 fingers.[59]

Plant reeds (*Phragmites australis*) have always been abundant in the marshes and wet regions of Mesopotamia and would serve as an ideal overflow mechanism for the dripping vessel. The maximum wall thickness for this species of reed is on average 0.8 mm, so a skilled craftsman could easily measure 1 finger from the floor of the dripping vessel and bore a hole to squeeze such a reed so that it was flush against the vessel's inner wall.[60] The reed's natural wall thickness would provide the extra 0.05 fingers required for the constant head. More importantly, a falling head for the supply vessel means that capillarity is once again an issue, with water flow stopping once the head reached a height h_c of 1.62 cm based on a 0.09 mm bore diameter. Water flowing through the reed could be collected in a separate overflow vessel and returned to the supply vessel when the flow rate of the latter had slowed to a few drips per second. Such replenishment of the supply vessel would be needed every 2.5 hours on average. All of the above demonstrates that the Babylonians would have been aware of capillary effects and

[59] Q = 0.104 ml/s = 0.104 cm^3/s; v = (0.104 cm^3/s)/π(0.09 cm/2)^2 = 16.3 cm/s; h_d = ((16.3 cm/s)^2/2 + 2(980 cm/s^2)(0.27 cm)^2/0.09 cm)/980 cm/s^2 = 1.76 cm.

[60] Angelika Wöhler-Geske *et al.*, "Use of image analysis for determination of morphological parameters of thatching reed," *Landtechnik* 68, no. 2 (2013): 110.

possibly used capillarity to establish a constant head rather than try to avoid capillarity effects altogether.

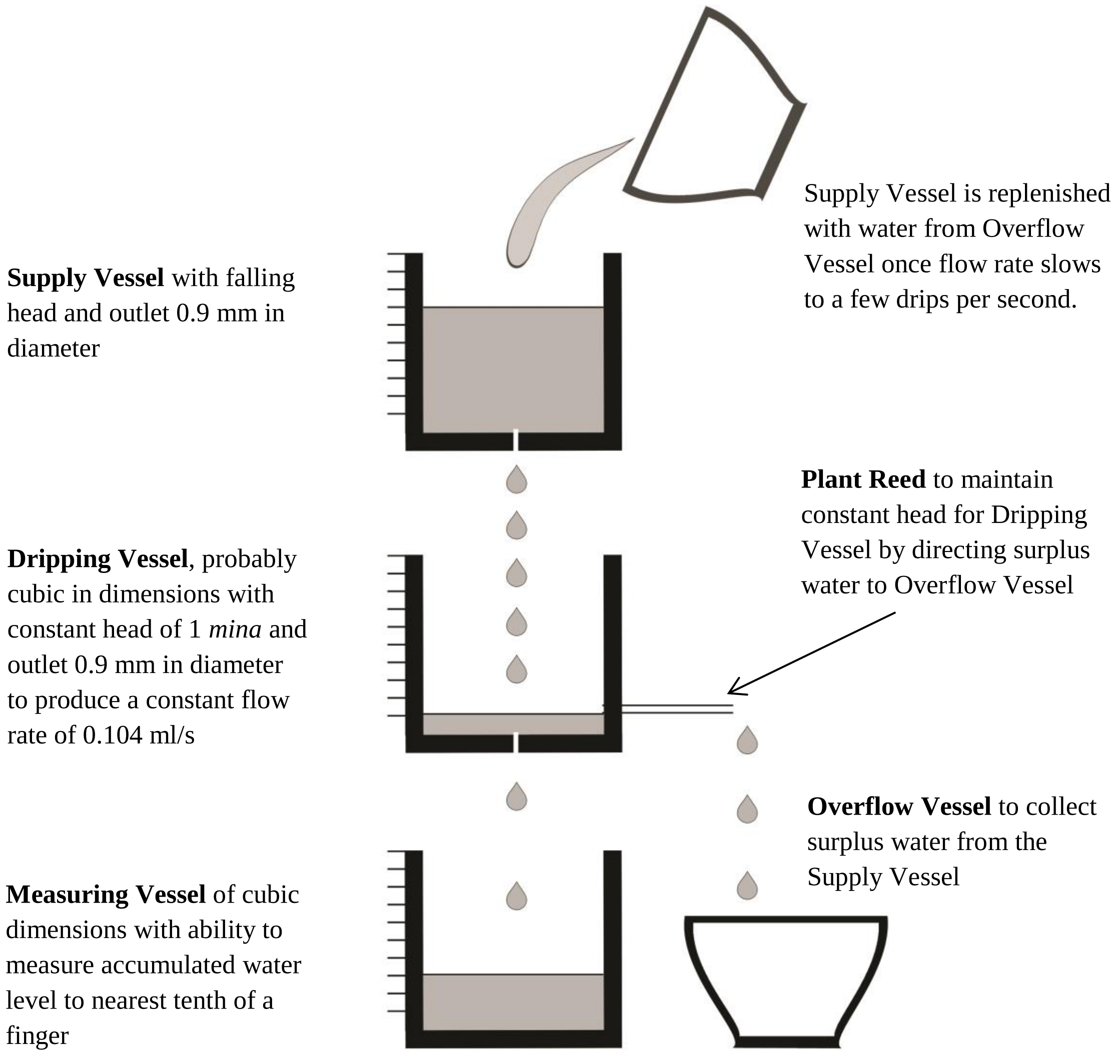

FIGURE 2: Potential design of water clock for Old Babylonian period

However, the use of a constant head and the need to replenish the supply vessel strongly suggest that the water clock was an inflow device. Thus, the verb *maqātu* in BM 85210 IV: 11 of the mathematical texts should be interpreted as water falling *into* a measuring vessel rather than falling *out* of a supply vessel.[61] Figure 2 contains a potential

[61] Brown, Fermor, and Walker, "The Water Clock in Mesopotamia," 134.

design of the water clock that attempts to address the issues so far discussed. The dimensions of 10 fingers cubed for the measuring vessel allow a change of 1 finger in water level to correspond roughly to 1 *mina* of water. Steele, Stephenson, and Morrison note that the average accuracy to which time on the water clock could be read is 8 minutes.[62] If we are correct in assuming that a tenth of finger was the smallest unit of length used in general practice, then the dimensions of the water clock proposed in this study confirm their observation. A water level change of this height translates to a volume of 0.09 *mina* (≈ 0.167 cm x 16.7 cm x 16.7 cm = 46.6 ml), which equates to just under 7.5 minutes in the "ideal year" scheme. From this, it is reasonable to conclude that the measuring vessel marked water levels to the nearest tenth finger.

3.2. Reconciling the 2:1 Ratio

Although the proposed two-stage design for the water clock helps us understand the capabilities and limitations of the device, it does nothing to explain the use of the 2:1 ratio between the lengths of day and night watches on the solstices. To provide some perspective using the summer solstice as an example, it is as if an astrologer recorded darkness as lasting for 8 hours when it actually lasted for 9 hours and 43 minutes. This vast discrepancy has led numerous scholars to believe that celestial interests were strictly divinatory and not in any sense astronomical prior to the eighth century BCE.

I contend, however, that the roots of 2:1 ratio are far more mundane. In his 1912 work on the first tablet of the MUL.APIN, King provides the following commentary on text concerning the water clock:

> An interesting indication of the practical character of the treatise may be seen in the facts that notes are given as to the payments made to the day and night watch respectively: during the six months from the 15th Tammuz to the 15th Tebet, the

[62] Steele, Stephenson, and Morrison, "The Accuracy of Eclipse Times," 344.

> day-watch was paid four [*minas*] and the night-watch two, but during the remainder of the year the payments were reversed, the night-watch receiving twice the pay of the day-watch. The observers who were on duty during the longer and colder nights of winter and the long scorching days of the summer months were naturally more highly recompensed.[63]

King's commentary is highly problematic because it suggests remuneration was based on average summer and winter temperatures, inapplicable during milder seasons, rather than time spent at labor. Nonetheless, it does introduce the notion that the 2:1 ratio served more to dictate wages than describe astronomical lengths of time. We must remember that the vast majority of ancient Mesopotamian labor was situated in the context of sunset and sunrise, so night and day watches for sentry duty, as an example, would have to be structured accordingly so that individuals arrived at their posts on time. In cases where day and night shifts are divided into three watches each, only the first and third watches of each shift are impacted by daylight and darkness length changes that occur throughout the year. The second watch of each shift can always remain at 4 hours or 3 *minas*. Interpreting the weights of the "ideal year" scheme in this manner results in a far more accurate 11:7 ratio (i.e. $\frac{4+3+4}{2+3+2}$) for the solstices than even the simple 3:2 approximation, with discrepancies from actual observations being at most 20 minutes instead of nearly 2 hours.

3.2.1. Detecting Equinoxes and Solstices

Tablet 14 of the *Enūma Anu Enlil* provides a means to test the above assumption of fixed second-watch lengths of 3 *minas* in the "ideal year" scheme. Table C of the tablet also lists the length of daylight and darkness (in *mina* and *šiqlu*) for the 15th and 30th day of each month in the Babylonian ideal calendar starting with Month I or *Nissanu*. For each half-month, the length of daylight or darkness changes by 10 *šiqlu* or a

[63] Cited in Neugebauer, "The Water Clock in Babylonian Astronomy," 38.

sixth of a *mina*.[64] Table 6 below compares lengths of daylight in the ideal calendar scheme with actual lengths of daylight observed from Babylon for each half-month in a tropical year. Since the ideal calendar presumes 12 months of 30 days each, half-months after the vernal equinox have 16 or 17 days and those after the autumnal equinox have 14 or 15 days in table 6 so as to better conform to a 365-day year.

As table 6 demonstrates, fixing the second watch to 3 *minas* and altering the first and third watches according to the Old Babylonian scheme outlined in Tablet 14 results in an average margin of error of 1.17%. This is extraordinary considering that an average margin of error of 1.1% stems automatically from the accuracy to which the water clock could have been read. The greatest margins of error occur around the solstices, primarily because lengths of daylight and darkness are roughly the same plus or minus 5-6 days for each solstice. But even these margins average to less than 4% (approximately 25 minutes), which is acceptable for these specific points in the year given both the general purpose of the water clock and its technological constraints. Nevertheless, an overall margin of error this small lends strong support to our assumption of fixed-length second watches. This potentially means that the Babylonians were adequately able to detect and measure equinoxes and solstices at the latest by 1600 BCE.

The two-stage water clock design proposed in this chapter would have allowed astrologers to consistently detect of equinoxes and solstices during the Old Babylonian period. As result, astrologers during this period would have also been able to determine the length of the solar year with ease and to begin experimenting with month lengths and intercalary months to reconcile the lunar calendar with the seasons. However, since the water clock can only assist individuals in measuring *observable* lengths of daylight and

[64] Hunger and Pingree, *Astral Sciences*, 47.

TABLE 6: Length of daylight comparison (Old Babylonian ideal calendar scheme vs. actual)

OB Month	Day Interval	Julian Day	Length of 1st/3rd Watch (*mina*)	Total Length of Daylight (*mina*)	Total Length of Daylight (hh:mm)	Actual Length of Daylight (hh:mm)	Margin of Error (%)
XII		Mar. 16	3	9	12:00	12:00	0.00
XII	16	Apr. 1	3 1/6	9 1/3	12:27	12:32	0.71
I	16	Apr. 17	3 1/3	9 2/3	12:53	13:03	1.23
I	16	May 3	3 1/2	10	13:20	13:32	1.48
II	16	May 19	3 2/3	10 1/3	13:47	13:55	1.00
II	16	June 4	3 5/6	10 2/3	14:13	14:11	0.27
III	17	June 21	4	11	14:40	14:17	2.68
III	16	July 7	3 5/6	10 2/3	14:13	14:12	0.16
IV	16	July 23	3 2/3	10 1/3	13:47	13:56	1.12
IV	16	Aug. 8	3 1/2	10	13:20	13:32	1.48
V	16	Aug. 24	3 1/3	9 2/3	12:53	13:04	1.36
V	16	Sep. 9	3 1/6	9 1/3	12:27	12:34	0.97
VI	17	Sep. 26	3	9	12:00	12:00	0.00
VI	14	Oct. 10	2 5/6	8 2/3	11:33	11:33	0.05
VII	14	Oct. 24	2 2/3	8 1/3	11:07	11:06	0.10
VII	14	Nov. 7	2 1/2	8	10:40	10:42	0.31
VIII	15	Nov. 22	2 1/3	7 2/3	10:13	10:20	1.08
VIII	14	Dec. 6	2 1/6	7 1/3	9:47	10:06	3.19
IX	14	Dec. 20	2	7	9:20	10:01	6.82
IX	14	Jan. 3	2 1/6	7 1/3	9:47	10:05	3.03
X	15	Jan. 18	2 1/3	7 2/3	10:13	10:19	0.92
X	14	Feb. 1	2 1/2	8	10:40	10:39	0.16
XI	14	Feb. 15	2 2/3	8 1/3	11:07	11:03	0.55
XI	14	Mar. 1	2 5/6	8 2/3	11:33	11:30	0.48
XII	15	Mar. 16	3	9	12:00	12:00	0.00

Note: Dates of actual daylight lengths are from March 16, 2016 to March 16, 2017. Coordinates used for location of Babylon are 32°32'N and 44°25'E.[65]

darkness, the equinox detected by astrologers in Babylon does not correspond to what we know as the true equinox. This is because days of equal daylight and darkness vary according to a location's latitude. Ancient Babylon, with a latitude of 32°32'N, experiences equal daylight and darkness 3-4 days *before* the true vernal equinox (March 20th) and 3-4 days *after* the true autumnal equinox (September 22nd), as table 6 illustrates. This issue is further complicated by the fact that *precession*, the slow and continuous movement of Earth's rotational axis that is similar to a spinning top, causes

[65] For actual daylight lengths, see United States Naval Observatory, "Duration of Daylight/Darkness Table for One Year," United States Navy, http://aa.usno.navy.mil/data/docs/dur_oneyear.php (accessed January 30, 2016).

the equinoxes and solstices to drift through the solar calendar over a 26,000 year period. Consequently, equinoxes and solstices that we experience at present occur 9-10 days earlier in the calendar than they did in the eighth century BCE. These final two points are often overlooked in modern scholarship and will become essential as we begin to explore the use of equinoxes and solstices in Babylonian calendrics.

3.3. Summary

References to the Babylonian water clock and its ability to detect cardinal phenomena can be found in numerous texts of the Old Babylonian period. However, reconstructing the clock in modern times has proved elusive, as scholars have struggled to propose designs which conform to the laws of fluid mechanics as well as the inscriptional and philological evidence. Most problematic of course is the “ideal year” scheme and its representation of a 2:1 ratio between lengths of daylight and darkness on solstices, the latter presumably measured by the water clock.

Mathematical exercises found in the Old Babylonian texts BM 85194 and BM85210 provide important clues as to the water clock’s design. When one specific variable in each exercise is reinterpreted as the cross-sectional area of the clock’s supply tank rather than its height, it becomes mathematically clear that the water clock employed cubic dimensions and was much smaller in volume than previously thought. Furthermore, a second dripping vessel with an overflow mechanism would have been required to ensure that water dripped at a desired, constant rate of two drops per second.

If we are correct in assuming that the clock measured water levels to the nearest tenth finger, then the device measured time with an average accuracy of 8 minutes, harmonizing with the findings of Steele, Stephenson, and Morrison. This level of precision forces us to eliminate the assumption that weights depicted in the "ideal year" scheme apply to all three watches in every shift. Fixing the second watch of each shift to 3 *minas* produces far more accurate ratios between lengths of daylight and darkness, resulting in margins of error that better align with the capabilities of the clock. All of these factors combined provide strong evidence that astrologers during the Old Babylonian period were reasonably capable of detecting equinoxes and solstices to determine when intercalary months needed to be inserted into their calendar.

CHAPTER 4: OLD BABYLONIAN CALENDRICS

Mesopotamian city-states were using numerous calendars as early as the middle of the third millennium BCE. So many were used in fact that pre-Sargonic period tablets (ca. 2350 BCE) attest to over 30 different month names, often with the same month name referring to different months depending on the calendar. As a result, a numbering convention of Months I-XII was soon established, presumably to alleviate confusion. In the Sumerian city of Nippur, home of the chief god Enlil, scribes had developed a calendar that was later adopted by Išbi-erra (ca. 2017-1985 BCE), the first king of the Dynasty of Isin, and was used throughout southern Mesopotamia for the next two centuries.[66] Sin-muballit of Babylon conquered the city of Isin circa 1793 BCE; and one year later, his son Hammurabi (ca. 1792-1750 BCE) ascended the throne and began extending Babylonian control over Mesopotamia.[67] By the end of his 42-year reign, Hammurabi had united all of Mesopotamia, with Amorite and Sumerian calendars being used in the northern and southern regions respectively.[68]

The assumption that each month began upon first visibility and sighting of the new moon crescent is firmly supported by Old Babylonian texts such as the creation epic

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[66] Mark E. Cohen, *The Cultic Calendars of the Ancient Near East* (Bethesda, MD: CDL Press, 1993), 9.

[67] I have opted to use Middle Chronology dating based on radiocarbon analysis conducted within the Aegean Dendrochronology Project. For full discussion, see Sturt W. Manning *et al.*, "Anatolian Tree Rings and a New Chronology for the East Mediterranean Bronze-Iron Ages," *Science* 294, no. 5551 (December 21, 2001): 2534.

[68] Cohen, *The Cultic Calendars*, 297.

of the *Enūma Eliš*. In Tablet V of the epic, the god Marduk commands the lunar phases with the full moon occurring at mid-month and the new moon at month's end:

> The Moon he caused to shine, the night (to him) entrusting.
> He appointed him a creature of the night to signify the days:
> "Monthly, without cease form designs with a crown.
> At the month's very start, rising over the land,
> Thou shalt have luminous horns to signify six days,
> On the seventh day reaching a [half]-crown.
> At full moon stand in opposition in mid-month.
> When the sun [overtakes] thee at the base of heaven,
> *Diminish* thy crown and retrogress in light.
> [At the time of disappearance] approach thou the course of the sun,
> And [on the twenty-ninth] thou shalt again stand in opposition to the sun."[69]

In addition, we find third millennium instances of intercalations at intervals of 2 and 3 years. Tablet V of the *Enūma Eliš* also states that Marduk established three constellations for each of the twelve months, which suggests that misalignment between a month and its assigned constellations was possibly used as a tool to determine the need for an intercalary month during this period.[70] Yet, there are several instances during the late third millennium when intervals of intercalation appear to be less consistent. During the reigns of Ur-III Dynasty kings Amar-sin and Šu-sin (ca. 2045-2028 BCE) for example, intercalations are attested in 4 successive years.[71] Irregularities are also attested in the second millennium BCE with 4 successive intercalations in years 32, 33, 34, and

[69] James B. Pritchard, *Ancient Near Eastern Texts Relating to the Old Testament*, 2nd ed. (Princeton: Princeton University Press, 1955), 66-67.

[70] Ibid.

[71] R. K. Englund, "Administrative Timekeeping in Ancient Mesopotamia," *Journal of the Economic and Social History of the Orient* 31, no. 2 (1988): 123-125n3.

35 of Hammurabi and no intercalary months between years 6 and 9 of Ammi-saduqa (ca. 1646-1626 BCE).[72]

Stern argues that these irregularities suggest that the insertion of an intercalary month was largely a matter of royal decree; however, successive intercalary years could be attempts to synchronize calendars from different regions as well.[73] The month of *Ajaru*, for instance, is the twelfth month in the Amorite calendar but the second month in the Sumerian calendar.[74] Transitioning from the Amorite calendar to the Sumerian version would require at least 3 successive intercalary years, if the aim was to align month names between the two systems. In the case of Hammurabi, the 4 successive intercalary years mentioned above translate to roughly a 2.5 month shift in the start of the calendar year.[75] After Hammurabi's unification of Mesopotamia, such a transition appears to have been completed during the reign of his son, Samsuiluna (ca. 1749-1712 BCE). By year 21 of Samsuiluna's reign, the Amorite calendar is no longer used to date documents; and we see Sumerian month names becoming logograms to represent the months of a Standard Mesopotamian calendar that gained wide acceptance over the next millennium.[76]

4.1. Calendrics during the Old Babylonian Period

Because celestial omens in the *Enūma Anu Enlil* are primarily formulaic and not linked to sequential observations, they are often dismissed as datable sources within

[72] P. J. Huber, *Astronomical Dating of Babylon I and Ur III*, Monographic Journals of the Near East, occasional papers 1/4 (Malibu, CA: Undena Publications, 1982), 8.

[73] Stern, *Calendars in Antiquity*, 94-95.

[74] Cohen, *The Cultic Calendars*, 310.

[75] Huber, *Astronomical Dating of Babylon I and Ur III*, 8.

[76] Cohen, *The Cultic Calendars*, 225, 297-304.

studies of Babylonian calendrics. Eclipse omens within the series nevertheless provide valuable insights into month lengths and intercalation methods of the Old Babylonian period. Each omen consists of a dependent clause or *protasis* that contains an astronomical phenomenon with potential month and day of occurrence as well as a main clause or *apodosis* that predicts an outcome affecting the king, the state, or the surrounding nations:

> If an eclipse occurs on the 14th day of Nisannu, and it begins in the south and [clears in the …]; it begins in the evening watch and clears in the middle watch. You observe his (the god's) eclipse and [you bear in mind the south]. The prediction is given for the king of Akkad: The king of Akkad will die. If the eclipse does not affect the king: There will be destruction and famine.
>
> If an eclipse occurs on the 15th day, and it (the god) disappears while it is in eclipse, and a meteor falls: Flood will devastate the land. The economy of the land will diminish.
>
> If an eclipse occurs on the 16th day, ditto, ditto (i.e. «and it disappears while in eclipse and a meteor falls»): The rains in the sky, the flood waters in the source will cease.
>
> If an eclipse occurs on the 20th day, ditto, ditto: King will send messages of hostility to king.
>
> If an eclipse occurs on the 21st day, ditto, ditto: The sea will dry up, the produce of the sea will fail. The grain will diminish in the shipping baskets. Grain will decrease. The economy will diminish.[77]

The above omen series reflects a structure that is commonly associated with omens of the Old Babylonian period in which five omens are assigned to days 14, 15, 16, 20, and 21 of each calendar month. The protasis is identical for all five omens while the apodosis for each varies depending on the day of occurrence for the lunar eclipse. This scheme is regarded as the "classical" pattern within celestial omen texts; although, it is important to mention that some Old Babylonian series occasionally assign omens to days 18 and 19 as

[77] Tablet XXI of the *Enūma Anu Enlil*; for translation, see Rochberg-Halton, *ABCD*, 233-234.

well. Even more peculiar is the complete omission of day 17 omens in series during this period, with the rationale for such an omission remaining a complete mystery.[78]

Of course, what immediately stands out in the classical pattern is the possibility of lunar eclipses occurring on days 20 and 21 of the lunar month. The Babylonians clearly understand that lunar eclipses can only occur during a full moon, the latter of which they had early situated at mid-month as evidenced by the *Enūma Eliš*. Moreover, any inhabitant of Mesopotamia could determine the progress of the current month by simply looking up and seeing which part of the Moon was illuminated as illustrated in figure 1. Therefore, recorded occurrences of lunar eclipses on days 20 and 21 must reflect the use of a schematic lunisolar calendar rather than an unperceived discrepancy of 6 or 7 days.

4.1.1. Month Lengths

Since their inception, Babylonian calendar months appear to have either 29 or 30 days; and certainly by the late sixth century BCE, we begin to see schematically a monthly alternation of "full" (30-day) and "hollow" (29-day) months as structured in Babylonian, Persian, and Hebrew calendars of this period. Alternating month-lengths in this fashion, however, limits possible lunar eclipse occurrences to the ideal days of 14 and 15 in the lunar month. If we start with the full moon occurring on the 14th of Month I for example, each calendar month for the year must only have 29 days in order for a lunar eclipse to have the possibility of occurring on the 20th of Month XII. Moreover, each calendar month in the subsequent year must contain 30 days in order to restore the possibility of eclipses occurring on the 14th of a month. Thus, omen series of the classical pattern in the *Enūma Anu Enlil* appear to reflect a yearly rather than monthly alternation of full and hollow months.

[78] Ibid., 38.

TABLE 7: Lunar eclipses within Old Babylonian schematic calendar

Month Day	Month Candidates	Full Moon Occurrences	Potential Eclipse Occurences	Visible Eclipse Occurrences
14	I, II, XII	7	2	1
15	I, II, III, IV, X, XI, XII	17	4	1
16	I, II, III, IV, V, VIII, IX, X, XI, XII	31	4	2
17	III, IV, V, VI, VII, VIII, IX, X, XI	38	7	0
18	IV, V, VI, VI_2, VII, VIII, IX	36	8	4
19	II, III, IV, V, VI, VII, VIII, IX, X, XI	29	5	2
20	II, III, IV, X, XI, XII	28	5	1
21	I, II, III, XII, XII_2	12	2	2
22	I	1	0	0

Appendix B provides a sample schematic calendar illustrating the above approach over two 8-year cycles from 743 to 727 BCE, with table 7 summarizing data related to full moon and lunar eclipse occurrences. Under the proposed calendar scheme, Old Babylonian omen series are clearly formulaic since the structure prevents months in the middle of the calendar from ever having eclipses that occur on days 14, 15, 20, and 21. Full moon and potential lunar eclipse occurrences appear to have a bell-curve distribution, with neither potential nor visible eclipse occurrences on day 22. Almost half of visible eclipses in the sample dataset occur on days 18 and 19, a finding that belies the occasional assignment of omens to these days under the classical pattern. However, this current distribution of visible eclipses can easily change with a different range of dates. It is quite possible that omen series reflecting the classical pattern were initially recorded during a period when visible lunar eclipses occurred more frequently in months towards the end and beginning of the calendar year (e.g. Months XI, XII, $XII_{2,}$ I, and II). But most surprising is that although day 17 is the most frequent day for full moon occurrences and second most frequent for potential lunar eclipses within this calendar scheme, no visible eclipse seems to occur for this day. This result may seem purely coincidental for the date range of appendix B; nevertheless, it confirms an empirical basis for the omission of day 17 in Old Babylonian omen series that could potentially date pertinent tablets of the *Enūma Anu Enlil*.

4.1.2. Intercalation

Although intercalary months have been used since the second millennium BCE, the earliest extant discussions of intercalation practices do not appear until the first millennium BCE with the MUL.APIN providing two different intercalary schemes. The first, as alluded to earlier, determines the need for an intercalary month by comparing the visibility of the moon in relation to certain constellations during the equinoxes and solstices. The second scheme is based on a simple rule of inserting an intercalary month every 3 solar years or 37 lunations. Neither of these schemes, however, appears to be used during the Old Babylonian period. As Hunger and Pingree note, constellations under the first scheme would be acceptable approximations for both solstices and the autumnal equinox (the constellations assigned to the vernal equinox in the scheme are extrapolated and not based on observations) but are only applicable to a few centuries before and after ca. 1000 BCE.[79] In addition, Old Babylonian administrative documents of 1-year rental home leases contain dates that include a mixture of intercalary months VI_2 and XII_2 during the reign of Hammurabi, suggesting at a minimum that intercalation intervals were not always in whole solar years.[80]

One potential clue concerning Old Babylonian intercalation procedures can be found in Tablet 63 of the *Enūma Anu Enlil*, which records over a 21-year period the rise

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[79] Hunger and Pingree, *MUL.APIN*, 151-153.

[80] Samuel Greengus, "The Akkadian Calendar at Sippar," *Journal of the American Oriental Society* 107, no. 2 (April – June 1987): 214-215.

times of Venus as well as its first and last visibilities on the horizon. Venus has a synodic period of 583.92 days or 20 lunar months minus approximately 6 days; and as it orbits the Sun, it becomes invisible to observers on Earth twice: (1) for 1-19 days when it passes between the Earth and Sun, known as an *inferior conjunction*, and (2) for 55-70 days when it passes behind the Sun, called a *superior conjunction*.[81] The start and end of each superior conjunction are regarded respectively as the moments of last visibility and first visibility. More importantly as these first and last visibilities migrate through the solar year, they return to their initial days of occurrence in an 8-year cycle—more precisely 99 lunations minus 4 days.

The first 10 omens of Tablet 63 contain visibilities for a full 8-year cycle of Venus, after which year 8 of Ammi-saduqa is inscribed.[82] This explicitly dates the omens of Tablet 63 to the entire reign of Ammi-saduqa (ca. 1646-1626 BCE). If the Babylonians were aware of the above 8-year cycle for Venus, then there is an extremely high probability that they we also cognizant of the 8-year cycle between lunar phases, equinoxes, and solstices. Therefore, it is certainly possible that Old Babylonian calendar schemes required 3 intercalations every 8 years as previously discussed.

It is often claimed that intercalary months were inserted to ensure that each calendar year began on or after the vernal equinox. This claim is based on Huber's work on Babylonian New Year conjunctions (i.e. the new moon immediately preceding 1 *Nisannu*) from the mid-eighth to fifth centuries BCE. According to Huber, the vernal equinox occurs on average 9 days before 1 *Nisannu* after ca. 610 BCE. Yet, it is

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[81] Huber, *Astronomical Dating of Babylon I and Ur III,* 11, 84.

[82] Erica Reiner and David Pingree, *Babylonian Planetary Omens. Part 1. The Venus Tablet of Ammisaduqa* (Malibu, CA: Undena Publications, 1975), 9.

important to note that this represents the average and not the full possible range of the vernal equinox occurring 30 days before and 18 days *after* the start of the calendar year.[83] Consequently, it would be erroneous to conclude from Huber's data that the Babylonians always intended the vernal equinox to occur in the last month of the year. Several fixed schemes for calculating equinoxes and solstices used during the fourth century BCE and later add further support to this position, with numerous recordings of the vernal equinox occurring on and after 2 *Nisannu*.[84]

With New Year conjunctions failing to support the assertion that the vernal equinox was always expected to occur before a specific calendar date, scholars like Stern maintain that there is no astronomical rationale between the equinoxes and Babylonian schematic calendars as previously mentioned. The "ideal year" scheme, however, suggests an attempt by the Babylonians to stabilize the summer solstice, autumnal equinox, winter solstice, and vernal equinox in Months III, VI, IX, and XII respectively. In the MUL.APIN and related Neo-Assyrian texts, these cardinal phenomena are shifted one month later; but Britton suspects that the emergence of the Neo-Babylonian Empire marks a return to the Old Babylonian tradition.[85] This study agrees with Britton's suspicion; therefore, the role of solstices in relation to lunar phases, specifically the new moon, is also explored in appendix B as a means of determining the need for intercalation within an 8-year schematic cycle.

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[83] Huber, *Astronomical Dating of Babylon I and Ur III*, 8-10.

[84] Stern, *Calendars in Antiquity*, 117nn123-125.

[85] Britton, "Calendars, Intercalations and Year-Lengths," 119.

The date range of appendix B has been selected to reflect Huber's analysis that the vernal equinox on average preceded the new moon by 9 days.[86] Furthermore, the initial vernal equinox of the sample dataset has intentionally been dated to 21 Month XII so that the new moon is observed on 30 Month XII (remembering that each calendar day begins after sunset). Notice in year 1 of each cycle that cardinal phenomenon, as potentially detected by the water-clock, fall either on or within a few days of the new moon. This lunisolar alignment marks the start of each 8-year cycle. All cardinal phenomena also occur in their respective months per the "ideal year" scheme, if we interpret the new moon to represent the official end of the lunar month. Conversely, each cycle ends with all cardinal phenomena occurring on or within a few days of the full moon in year 8, which most likely provides the empirical basis for the "ideal year" scheme with equinoxes and solstices occurring at their respective mid-months.

In year 2 of the first cycle in appendix B, the summer solstice (-741 July 1) undoubtedly occurs after the new moon by more than 7 days and well into Month IV. I contend that such an occurrence indicates the need for an intercalary month VI_2. Once inserted, the other cardinal phenomena occur in their assigned months rather than each drifting a month later into the calendar. A similar situation also occurs for the summer

[86] Huber does not explicitly mention the vernal equinox occurring on average 9 days before New Year conjunctions during the Neo-Babylonian period, but this fact can be discerned easily from his data (Huber, *Astronomical Dating of Babylon I and Ur III*, 9). Using the work of Hunger and Sachs on Neo-Assyrian lunar eclipse records dating from 728 to 625 BCE, Huber notes that the vernal equinox occurred on average 14 days *after* New Year conjunctions (i.e. 14 Month I rather than 21 Month XII) in harmony with the calendar scheme detailed in the MUL.APIN. This dramatic change of average vernal equinox occurrences in relation to New Year conjunctions suggests an institutional shift in calendric procedures during the Neo-Babylonian period, which per Britton this study interprets as having roots in the Old Babylonian tradition.

Preliminary experimentation reveals that the length of time between the initial vernal equinox and New Year conjunction of an 8-year cycle equals the average length of time between the two phenomena for the entire cycle. For example, if the initial length of time between the two phenomena was -6 days (i.e. the vernal equinox occurred 6 days prior to the New Year conjunction), then the average length of time between the two phenomena for the entire 8-year cycle would also be -6 days.

solstice in year 5 (-738 July 1). In year 7, the summer solstice (-736 June 30) occurs again after the new moon but this time within a few a days. Recall from chapter 3 that lengths of daylight and darkness are roughly the same for 5-6 days surrounding each solstice. Therefore, the Babylonians probably waited for a more clear indication to insert an intercalary month. The occurrence of the winter solstice (-736 December 27) 6 days after the new moon provides such an indication, with the insertion of an intercalary month XII_2 again restoring occurrences of the other cardinal phenomena to their assigned months. Thus, we have an 8-year schematic cycle with 3 intercalations at intervals of 2.5 or 3 years that also demonstrates the need for both intercalary months VI_2 and XII_2 as observed during the Old Babylonian period. More importantly, the rules of intercalation appear to be very simple under the Old Babylonian tradition:

1. If the *summer solstice* occurs undoubtedly after the new moon immediately following the end of Month III (i.e. after 6 or more days), insert an intercalary month $VI_{2.}$
2. If the *winter solstice* occurs undoubtedly after the new moon immediately following the end of Month IX (i.e. after 6 or more days), insert an intercalary month $XII_{2.}$

By using the solstices to determine intercalation, the Babylonians would know to insert an intercalary month by as much as 70 days in advance, doubling the range confirmed by Samuel Greengus from Old Babylonian administrative documents.[87]

It is important to note that years of intercalation are by no means fixed within the Old Babylonian scheme. Whereas intercalary years in the Metonic cycle and the hypothesized *octaeteris* are determined arithmetically to prevent the epact from exceeding 30 days, intercalary years under the Old Babylonian tradition can fluctuate depending on solstice and new moon occurrences. For example, year 7 of the first 8-year

[87] Greengus, “The Akkadian Calendar at Sippar,” 214n20.

cycle in appendix B requires the insertion of an intercalary month XII_2. In the next cycle, however, an intercalary month VI_2 is inserted into year 8 since both solstices of year 7 are within a few days of the new moon. Consequently, Babylonian intercalation patterns are nearly impossible to detect if one ignores cardinal phenomena within each cycle.

4.1.3. Calendar Drift vs. Extra Days

As previously stated, 99 synodic months exceeds 8 solar years by 1.5 days or 3 days over two 8-year cycles. This surplus of lunar days has the potential to cause lunar phases and eclipse occurrences to drift through the calendar such that either occur on any given day of the month. Under the proposed Old Babylonian calendar scheme, new moons would eventually occur on day 15 and full moons on day 30 after only a few cycle iterations. The issue of calendar drift appears to have been addressed in the Neo-Assyrian period via the adjustment of month days when the new moon no longer coincided with its expected date:

> To the king, [my lo]rd, (from) your servant Adad-[šumu-usur]:
> Good health to the king, [my lord]! May the gods of Aššūr, Sîn, and Šamaš, [Nabû, Marduk] (and) the great gods of heaven [and earth] very much bless the king, my lord.
> (When) I first observed the (crescent of the) Moon on the 30th day, it was (already) high, (too) high to be (the crescent) of the 30th. Its position was like that of the 2nd day. (So), if it suits the king, my lord, the king should wait for the report of Assur before fixing the date. Perhaps the king, my lord, (now) says: "Why didn't you decide (about the matter)?" (*Break*)
> The king should [inquire] the scri[bes]; the days […] (*remainder lost*)[88]

As evidenced in the above letter from the exorcist Adad-šumu-usur to Aššurbanipal (668-627 BCE), the first day of a month could be slightly adjusted if there was clear evidence that the first crescent had been observed too late (or too early). Adad-šumu-usur asks the king to wait before "fixing the date," presumably to mitigate calendar drift by revising

[88] *ABL* 894; trans. Parpola, *LAS*, vol. 1, 89.

the month to have 29 days so that day 30 now becomes day 1 of the next month. Parpola notes in his commentary that the frequency at which the king really took the trouble to adjust the calendar by decree is at best speculative, but the letter does seem to suggest that the need for such decisions was rare given the exorcist's attempt to explain why he had not already addressed the matter on his own.[89]

It is clear from the "classical pattern" that the Babylonians had established a similar approach to ensure that full moon and lunar eclipse occurrences remained between days 14-21. I argue this was accomplished by inserting an extra day into the calendar to prevent the new moon from occurring on the 7th of the month or later. One added advantage of this proposed strategy is that it practically eliminates the full moon from occurring on day 22 or later, aligning well with the "classical pattern." Moreover, it is quite possible that another method for inserting extra days could have been used—namely when the new moon failed to return to day 30 towards the end of even-numbered cycle years; but this approach becomes increasingly difficult since insertions can only be determined in hindsight one month later at a minimum rather than within a week of the new moon occurrence as with the Neo-Assyrian example.

In the sample dataset of appendix B, an extra day is not required until year 7 of the first cycle to prevent the new moon (-735 January 20) from occurring on 7 Month XI. This is achieved by revising Month X to have 30 instead of 29 days. Another extra day must be inserted uncommonly soon in Month XII_2; nevertheless, the insertion of both of these days enables the cycle to end with the new moon (-734 April 8) occurring on 30 Month XII just as it had in the previous cycle. A third insertion is not needed until year 7 of the next cycle with the new moon in Month XII (-727 February 20), which again

[89] Parpola, *LAS*, vol. 2, 101-102.

allows the final new moon of the cycle to occur on 30 Month XII. Hence, the surplus lunar days expected over a 16-year period are satisfied by revising three 29-day months so that each has 30 days.

Just as with intercalary months, the insertion of extra days is not fixed to specific years within each cycle but can fluctuate depending on new moon occurrences. The structure of the proposed calendar scheme causes new moon dates to drift towards day 7 near the end of odd-numbered cycle years when all months are allocated 29 days. Therefore, adding an extra day to a 29-day month could be a likely method in which astrologers of the Old Babylonian period mitigated calendar drift. More importantly, this combination of non-fixed months with 30 days potentially explains why prior scholarship has failed to detect the presence of “leap” days in Babylonian calendar schema, particularly since it has assumed that month lengths are determined solely by visual confirmation.

4.2. Summary

Astrologers practicing during the Old Babylonian period clearly know that lunar eclipses can only occur at the middle of each lunation, yet numerous omens composed during this time reflect a structure in which full moons and lunar eclipses can occur as late as days 20 and 21 of the lunar month. This scheme requires the use of fixed rather than visually-confirmed month lengths in order to accommodate and maintain a 7-day range of possible eclipse days. As demonstrated in this chapter, the only way to achieve this structure is for all months in a year to alternate between having 29 or 30 days.

Moreover, since the Babylonians were aware that the first and last visibilities of Venus occur in an 8-year cycle during the seventeenth century BCE, it is very likely that they were cognizant of the 8-year lunisolar cycle as well. It is certainly possible, as shown in appendix B, that the latter provided the basis for intercalation during the Old Babylonian period. However, rather than fix intercalation at years 3, 5/6, and 8 as with the *octaeteris*, the Babylonians developed fixed rules of intercalation to stabilize cardinal phenomena in specific months as outlined in the “ideal year” scheme. Replicating these rules within an 8-year lunisolar cycle produces the astonishing result of each equinox and solstice, as detected by the water clock, occurring on or near the new moon in the first year and on or near the full moon in the eighth year. This strongly suggests that the “ideal year” scheme represents an idealized depiction of the last year in each cycle. We thus have evidence of the Babylonians employing a sophisticated, lunisolar calendar scheme early in the second millennium BCE.

CHAPTER 5: CONCLUSION

> Do you believe then that the sciences would ever have arisen and become great if there had not beforehand been magicians, alchemists, astrologers and wizards?
>
> —Friedrich Nietzsche

Many regard Galileo Galilei (1564-1642 CE) as the "father of observational astronomy," but few are aware that he and Johannes Kepler (1571-1630 CE) were also noted astrologers of their time. Galileo's reputation for casting horoscopes is said to have brought requests (and lucrative high fees) from cardinals, princes, and patricians. Moreover, his extensive attempts to calculate birth charts for himself and his daughters, Virginia and Livia, suggest that he held some value to the practice.[90] Kepler's devotion to the craft is evident with his publication of 18 astrological almanacs over the course of his life.[91] In addition, Isaac Newton (1642-1727 CE) is known to have devoted much of his time toward the areas of biblical prophecy and eschatology, using his knowledge of the precession of equinoxes to revise ancient chronology and to predict the final apocalypse in the book of Revelation to occur in 2060.[92] Europe in the seventeenth century CE thus reflects a period in which scientists doubled as astrologers and prophets, all in an effort to understand the laws and rules by which perceived supernatural forces interacted with the natural world. Yet, no one argues that the contributions of Galileo, Kepler, and Newton

[90] J. L. Heilbron, *Galileo* (Oxford: Oxford University Press, 2010), 90-93.

[91] Benson Bobrick, *The Fated Sky* (New York: Simon & Schuster, 2005), 162.

[92] Gale E. Christianson, *Isaac Newton* (Oxford: Oxford University Press, 2005), 61.

no longer constitute as science simply because they applied their knowledge to non-scientific endeavors.

Likewise for Babylonia in the seventeenth century BCE, there was no distinction between astrologer and astronomer. The individuals occupying these roles were one in the same; and they (1) meticulously recorded lunar and planetary observations, (2) made predictions, (3) built apparatuses to improve the precision of those observations and predictions, and (4) established rules to align the reckoning of time with reoccurring phenomena. Again, all of these activities were conducted with the aim of understanding the laws by which unseen forces (in the form of their gods) affected the ancient world and its affairs.

Whether the interplay between religion and science is more explicit during the Old Babylonian period or conveniently ignored during Europe's scientific revolution, a persistent bias embedding modern scholarship is that the religious pursuits of the Babylonians negatively impacted their powers of observation. Consequently, lunar eclipses recorded on day 21 of a month or daylight/darkness ratios of 2:1 are perceived as gross errors rather than as signs of intentional structure. Another pervasive bias, to borrow from Franz Boas, is that Hellenistic culture "represents the highest cultural development" of the ancient world "toward which all other more primitive cultural types tend;" and we, therefore, reconstruct an orthogenetic development towards Greek civilization.[93] In other words, we assume that all paths of scientific innovation lead to Athens, with parallel achievements either being inferior or occurring in close chronological proximity.

[93] Franz Boas, "The Methods of Ethnology," *American Anthropologist* 22, no. 4 (October-December, 1920): 312.

We certainly cannot deny the role of cultural diffusion between ancient Near Eastern and Mediterranean societies. However, the primary goal of this study has been to illustrate how the discovery of period relations between cardinal phenomena and lunar phases could enable any civilization to embark on its own trajectory of calendar development. The Mesopotamian trajectory appears to be best characterized as a gradual shift from annual to semiannual to monthly alternations of month lengths of 29 to 30 days. Furthermore, while the Hellenistic approach seeks to reconcile the epact arithmetically with fixed points of intercalation at the end of specific years, Babylonian calendrical rules are designed to insert intercalary months whenever lunisolar phenomena reveal that the epact has reached a certain threshold. The degree to which Babylonian calendrics influenced Hellenistic calendar developments remains unknown. Nevertheless, it is clear from the prominence of the "classical pattern" in lunar eclipse omens of the *Enūma Anu Enlil*, the invention of the water-clock, as well as knowledge of Venus and New Year conjunctions during the first half of the second millennium BCE that the Babylonians had already been using their own 8-year lunisolar cycle more than a thousand years before the earliest appearances of the *octaeteris* in Greece.

By uncovering the basic strategies of Babylonian calendrics, this study opens numerous opportunities in the field of astronomical chronology (the dating of historical events that are associated with astronomical observations). We can now potentially replace year approximations of key events with absolute dates and more easily identify discrepancies between textual sources to resolve problematic chronologies. But more importantly, we can also begin to rewrite the history of astronomy with its birthplace now in ancient Babylon.

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APPENDIX A: SAROS FIVE-MONTH LUNAR ECLIPSE DISTRIBUTIONS

The following table applies the Saros scheme of 8-7-8-7-8 as proposed by John M. Steele for the distribution of lunar eclipses occurring after five-month intervals (as opposed to the more common six-month intervals) for two Saros series starting from 747 BCE. This scheme is compared against an actual distribution of five-month interval eclipses (rows highlighted in bold) as well as a distribution that would have been observable to Babylonian astronomers. See chapter 1 for detailed analysis of the distributions.

Column Descriptions

LC:	long count of actual days since the initial event
EI (Days):	lunar eclipse interval in days
Eclipse Date:	Julian date of lunar eclipse (expressed in astronomical year numbering in which the year 0 = 1 BCE, −1 = 2 BCE, etc.)
Eclipse Visibility:	visibility of the lunar eclipse from within Babylonia
SE Num.:	Saros series lunar eclipse number from 1 to 38
EI (Months):	lunar eclipse interval in months; five-month eclipse interval events are in bold
8-7-8-7-8 Scheme:	proposed Saros distribution of 8-7-8-7-8 for lunar eclipses occurring after five month intervals
Observ. Scheme:	actual distribution of observable lunar eclipses occurring after five month intervals from within Babylonia

LC	EI (Days)	Lunar Eclipse Date	Eclipse Visibility	SE #	EI (Months)	8-7-8-7-8 Scheme	Observ. Scheme
0	**149**	**-746 Feb. 6**	**Partial eclipse**	**1**	**5**		
177	177	-746 Aug. 2	Total eclipse	2	6		
354	177	-745 Jan. 26	Total eclipse	3	6		
531	177	-745 July 22	Partial eclipse	4	6		
708	177	-744 Jan. 15	Eclipse not visible	5	6		
885	177	-744 July 10	Eclipse not visible	6	6		
1033	148	-744 Dec. 5	Eclipse not visible		5		
1062	29	-743 Jan. 3	Eclipse not visible	7	1		
1210	**148**	**-743 May 31**	**Eclipse not visible**	**8**	**5**		
1388	178	-743 Nov. 25	Near total eclipse	9	6	8	8
1564	176	-742 May 20	Partial eclipse	10	6		
1742	178	-742 Nov. 14	Partial eclipse	11	6		
1919	177	-741 May 10	Partial eclipse	12	6		
2096	177	-741 Nov. 3	Partial eclipse	13	6		
2244	148	-740 Mar. 30	Eclipse not visible		5		
2273	29	-740 Apr. 28	Eclipse not visible	14	1		
2420	**147**	**-740 Sep. 22**	**Eclipse not visible**	**15**	**5**		
2599	179	-739 Mar. 20	Near total eclipse	16	6	7	7
2775	176	-739 Sep. 12	Partial eclipse	17	6		
2953	178	-738 Mar. 9	Eclipse not visible	18	6		
3129	176	-738 Sep. 1	Total eclipse	19	6		
3307	178	-737 Feb. 26	Eclipse not visible	20	6		
3484	177	-737 Aug. 22	Eclipse not visible	21	6		
3631	**147**	**-736 Jan. 16**	**Eclipse not visible**	**22**	**5**		
3809	178	-736 July 12	Eclipse not visible		6		
3838	29	-736 Aug. 10	Eclipse not visible	23	1		
3986	148	-735 Jan. 5	Eclipse not visible	24	5	8	8
4163	177	-735 July 1	Total eclipse	25	6		
4340	177	-735 Dec. 25	Total eclipse	26	6		
4517	177	-734 June 20	Total Eclipse	27	6		
4695	178	-734 Dec. 15	Eclipse not visible	28	6		
4871	176	-733 June 9	Eclipse not visible	29	6		
5020	**149**	**-733 Nov. 5**	**Eclipse not visible**	**30**	**5**		
5197	177	-732 Apr. 30	Partial eclipse	31	6	7	7
5374	177	-732 Oct. 24	Eclipse not visible	32	6		
5551	177	-731 Apr. 19	Total eclipse	33	6		
5728	177	-731 Oct. 13	Eclipse not visible	34	6		
5906	178	-730 Apr. 9	Eclipse not visible	35	6		
6082	176	-730 Oct. 2	Partial eclipse	36	6		
6231	**149**	**-729 Feb. 28**	**Eclipse not visible**	**37**	**5**		
6407	176	-729 Aug. 23	Eclipse not visible	38	6		
6437	30	-729 Sep. 22	Eclipse not visible		1		
6585	148	-728 Feb. 17	Eclipse not visible	1	5	8	
6762	177	-728 Aug. 12	Eclipse not visible	2	6		
6939	177	-727 Feb. 5	Eclipse not visible	3	6		
7116	177	-727 Aug. 1	Total eclipse	4	6		11
7293	177	-726 Jan. 25	Partial eclipse	5	6		
7471	178	-726 July 22	Eclipse not visible	6	6		

LC	EI (Days)	Lunar Eclipse Date	Eclipse Visibility	SE #	EI (Months)	8-7-8-7-8 Scheme	Observ. Scheme
7618	147	-726 Dec. 16	Eclipse not visible		5		
7648	30	-725 Jan. 15	Eclipse not visible	7	1		
7795	**147**	**-725 June 11**	**Eclipse not visible**	**8**	**5**		
7973	178	-725 Dec. 6	Eclipse not visible	9	6	8	
8149	176	-724 May 30	Total eclipse	10	6		6
8327	178	-724 Nov. 24	Total eclipse	11	6		
8504	177	-723 May 20	Eclipse not visible	12	6		
8682	178	-723 Nov. 14	Partial eclipse	13	6		
8829	147	-722 Apr. 10	Eclipse not visible		5		
8859	30	-722 May 10	Eclipse not visible	14	1		
9006	**147**	**-722 Oct. 4**	**Eclipse not visible**	**15**	**5**		
9184	178	-721 Mar. 31	Eclipse not visible	16	6	7	
9360	176	-721 Sep. 23	Eclipse not visible	17	6		
9538	178	-720 Mar. 19	Total eclipse	18	6		8
9715	177	-720 Sep. 12	Total eclipse	19	6		
9892	177	-719 Mar. 8	Partial eclipse	20	6		
10069	177	-719 Sep. 1	Partial eclipse	21	6		
10217	**148**	**-718 Jan. 27**	**Eclipse not visible**	**22**	**5**		
10394	177	-718 July 23	Eclipse not visible	23	6		
10424	30	-718 Aug. 22	Eclipse not visible		1		
10571	147	-717 Jan. 16	Partial eclipse	24	5	8	6
10749	178	-717 July 13	Partial eclipse	25	6		
10926	177	-716 Jan. 6	Total eclipse	26	6		
11103	177	-716 July 1	Eclipse not visible	27	6		
11280	177	-716 Dec. 25	Partial eclipse	28	6		
11457	177	-715 June 20	Eclipse not visible	29	6		
11605	**148**	**-715 Nov. 15**	**Eclipse not visible**	**30**	**5**		
11782	177	-714 May 11	Eclipse not visible	31	6	7	
11959	177	-714 Nov. 4	Partial eclipse	32	6		8
12137	178	-713 May 1	Total eclipse	33	6		
12313	176	-713 Oct. 24	Total eclipse	34	6		
12491	178	-712 Apr. 19	Partial eclipse	35	6		
12667	176	-712 Oct. 12	Partial eclipse	36	6		
12816	149	-711 Mar. 10	Eclipse not visible		5		
12846	30	-711 Apr. 9	Eclipse not visible	37	1		
12992	146	-711 Sep. 2	Eclipse not visible		5		
13022	30	-711 Oct. 2	Eclipse not visible	38	1		
13170	**148**	**-710 Feb. 27**	**Partial eclipse**	**1**	**5**	**8**	**7**

APPENDIX B: OLD BABYLONIAN PERIOD SAMPLE CALENDRICAL TABLE

The following table represents a sample 8-year or *octaeteris* calendar scheme for the Old Babylonian period. All data in the table are calculated using astronomical algorithms from Meeus.[94] Delta T (ΔT) adjustments for the eighth century BCE have been obtained from Morrison and Stephenson.[95] The new moon of -742 April 7 has been set to the Babylonian date of 30 Month XII for illustrative purposes. Since days begin at sunset, events with times between 0:00 UT and sunset UT+3 actually occur one day prior to the Babylonian date indicated.

Column Descriptions

CY:	cycle year number from 1 to 8
SM:	synodic month number within the eight-year cycle
ML:	month length in days
LC:	long count of actual days since the initial event
Julian Date:	Julian date of lunar event (expressed in astronomical year numbering in which the year 0 = 1 BCE, −1 = 2 BCE, etc.)
Babylonian Date:	Babylonian date as day and month with VI_2 and XII_2 indicating intercalary months
Event:	astronomical event that occurred
Time (UT):	universal time (UT) of the mid-point of the astronomical event
Comments:	notes pertaining to the astronomical event

[94] Jean Meeus, *Astronomical Algorithms*.

[95] L.V. Morrison and F. R. Stephenson, "Historical Errors of the Earth's Clock Error," 332.

CY	SM	ML	LC	Julian Date	Babylonian Date	Time (UT)	Event	Comments
8	99	30	1	**-742 Mar. 22**	**15 Month XII**	**17:09**	**Full Moon**	
			7	*-742 Mar. 28*	*21 Month XII*	*21:28*	*Vernal Equinox*	
			17	-742 Apr. 7	1 Month I	04:33	New Moon	
1	1	29	31	**-742 Apr. 21**	**15 Month I**	**02:50**	**Full Moon**	
			46	-742 May 6	1 Month II	15:41	New Moon	
	2	29	60	**-742 May 20**	**15 Month II**	**13:57**	**Lunar Eclipse**	Not visible
			76	-742 June 5	2 Month III	00:02	New Moon	
	3	29	90	**-742 June 19**	**16 Month III**	**02:55**	**Full Moon**	
			102	*-742 July 1*	*28 Month III*	*02:19*	*Summer Solstice*	
			105	-742 July 4	2 Month IV	08:40	New Moon	
	4	29	119	**-742 July 18**	**16 Month IV**	**17:42**	**Full Moon**	
			134	-742 Aug. 2	2 Month V	16:08	New Moon	
	5	29	149	**-742 Aug. 17**	**17 Month V**	**09:56**	**Full Moon**	
			164	-742 Sep. 1	3 Month VI	00:01	New Moon	
	6	29	179	**-742 Sep. 16**	**18 Month VI**	**03:02**	**Full Moon**	
			193	-742 Sep. 30	3 Month VII	09:58	New Moon	
			193	*-742 Sep. 30*	*3 Month VII*	*22:50*	*Autumnal Equinox*	
1	7	29	208	**-742 Oct. 15**	**18 Month VII**	**20:11**	**Full Moon**	
			222	-742 Oct. 29	3 Month VIII	22:01	New Moon	
	8	29	238	**-742 Nov. 14**	**19 Month VIII**	**12:21**	**Lunar Eclipse**	Not visible
			252	-742 Nov. 28	4 Month IX	12:28	New Moon	
	9	29	268	**-742 Dec. 14**	**20 Month IX**	**02:35**	**Full Moon**	
			282	-742 Dec. 28	5 Month X	04:50	New Moon	
			282	*-742 Dec. 28*	*5 Month X*	*10:12*	*Winter Solstice*	
	10	29	297	**-741 Jan. 12**	**20 Month X**	**14:30**	**Full Moon**	
			311	-741 Jan. 26	5 Month XI	22:14	New Moon	
	11	29	327	**-741 Feb. 11**	**21 Month XI**	**00:01**	**Full Moon**	
			341	-741 Feb. 25	6 Month XII	15:42	New Moon	
	12	29	356	**-741 Mar. 12**	**21 Month XII**	**08:47**	**Full Moon**	
			371	-741 Mar. 27	7 Month I	08:20	New Moon	
			373	*-741 Mar. 29*	*9 Month I*	*03:18*	*Vernal Equinox*	
2	13	30	385	**-741 Apr. 10**	**21 Month I**	**16:41**	**Full Moon**	
			400	-741 Apr. 25	6 Month II	23:19	New Moon	
	14	30	415	**-741 May 10**	**21 Month II**	**00:02**	**Lunar Eclipse**	Partial
			430	-741 May 25	6 Month III	12:08	New Moon	
	15	30	444	**-741 June 8**	**20 Month III**	**10:09**	**Full Moon**	
			459	-741 June 23	5 Month IV	22:50	New Moon	
			467	*-741 July 1*	*13 Month IV*	*08:08*	*Summer Solstice*	
	16	30	473	**-741 July 7**	**19 Month IV**	**21:11**	**Full Moon**	
			489	-741 July 23	5 Month V	08:00	New Moon	
	17	30	503	**-741 Aug. 6**	**19 Month V**	**10:38**	**Full Moon**	
			518	-741 Aug. 21	4 Month VI	16:39	New Moon	
	18	30	533	**-741 Sep. 5**	**19 Month VI**	**02:48**	**Full Moon**	
			548	-741 Sep. 20	4 Month VI_2	01:45	New Moon	
			559	*-741 Oct. 1*	*15 Month* VI_2	*04:37*	*Autumnal Equinox*	
	19	30	562	**-741 Oct. 4**	**18 Month** VI_2	**21:14**	**Full Moon**	
			577	-741 Oct. 19	3 Month VII	11:58	New Moon	

CY	SM	ML	LC	Julian Date	Babylonian Date	Time (UT)	Event	Comments
2	20	30	592	**-741 Nov. 3**	**18 Month VII**	**16:28**	**Lunar Eclipse**	Partial
			606	-741 Nov. 17	2 Month VIII	23:28	New Moon	
	21	30	622	**-741 Dec. 3**	**18 Month VIII**	**10:36**	**Full Moon**	
			636	-741 Dec. 17	2 Month IX	12:08	New Moon	
			647	*-741 Dec. 28*	*13 Month IX*	*15:57*	*Winter Solstice*	
	22	30	652	**-740 Jan. 2**	**18 Month IX**	**02:13**	**Full Moon**	
			666	-740 Jan. 16	2 Month X	01:54	New Moon	
	23	30	681	**-740 Jan. 31**	**17 Month X**	**14:57**	**Full Moon**	
			695	-740 Feb. 14	1 Month XI	16:47	New Moon	
	24	30	711	**-740 Mar. 1**	**17 Month XI**	**01:13**	**Full Moon**	
			725	-740 Mar. 15	1 Month XII	08:37	New Moon	
			738	*-740 Mar. 28*	*14 Month XII*	*09:16*	*Vernal Equinox*	
	25	30	740	**-740 Mar. 30**	**16 Month XII**	**09:42**	**Lunar Eclipse**	Not visible
			755	-740 Apr. 14	1 Month I	00:02	New Moon	
3	26	29	769	**-740 Apr. 28**	**15 Month I**	**17:05**	**Lunar Eclipse**	Not visible
			784	-740 May 13	1 Month II	16:15	New Moon	
	27	29	799	**-740 May 28**	**16 Month II**	**00:00**	**Full Moon**	
			814	-740 June 12	2 Month III	06:22	New Moon	
	28	29	828	**-740 June 26**	**16 Month III**	**07:51**	**Full Moon**	
			832	*-740 June 30*	*20 Month III*	*14:07*	*Summer Solstice*	
			843	-740 July 11	2 Month IV	18:56	New Moon	
	29	29	857	**-740 July 25**	**16 Month IV**	**17:17**	**Full Moon**	
			873	-740 Aug. 10	3 Month V	06:20	New Moon	
	30	29	887	**-740 Aug. 24**	**17 Month V**	**05:33**	**Full Moon**	
			902	-740 Sep. 8	3 Month VI	17:11	New Moon	
	31	29	916	**-740 Sep. 22**	**17 Month VI**	**21:13**	**Lunar Eclipse**	Not visible
			924	*-740 Sep. 30*	*25 Month VI*	*10:35*	*Autumnal Equinox*	
			932	-740 Oct. 8	4 Month VII	03:57	New Moon	
3	32	29	946	**-740 Oct. 22**	**18 Month VII**	**15:46**	**Full Moon**	
			961	-740 Nov. 6	4 Month VIII	14:46	New Moon	
	33	29	976	**-740 Nov. 21**	**19 Month VIII**	**11:37**	**Full Moon**	
			991	-740 Dec. 6	5 Month IX	01:38	New Moon	
	34	29	1006	**-740 Dec. 21**	**20 Month IX**	**06:45**	**Full Moon**	
			1012	*-740 Dec. 27*	*26 Month IX*	*21:55*	*Winter Solstice*	
			1020	-739 Jan. 4	5 Month X	12:39	New Moon	
	35	29	1035	**-739 Jan. 19**	**20 Month X**	**23:43**	**Full Moon**	
			1050	-739 Feb. 3	6 Month XI	00:01	New Moon	
	36	29	1065	**-739 Feb. 18**	**21 Month XI**	**13:53**	**Full Moon**	
			1079	-739 Mar. 4	6 Month XII	12:46	New Moon	
	37	29	1095	**-739 Mar. 20**	**22 Month XII**	**01:15**	**Lunar Eclipse**	Partial
			1103	*-739 Mar. 28*	*1 Month I*	*15:13*	*Vernal Equinox*	
			1109	-739 Apr. 3	7 Month I	02:26	New Moon	
4	38	30	1124	**-739 Apr. 18**	**22 Month I**	**10:10**	**Full Moon**	
			1138	-739 May 2	6 Month II	16:57	New Moon	
	39	30	1153	**-739 May 17**	**21 Month II**	**17:21**	**Full Moon**	
			1168	-739 June 1	6 Month III	07:53	New Moon	
	40	30	1182	**-739 June 15**	**20 Month III**	**23:51**	**Full Moon**	

CY	SM	ML	LC	Julian Date	Babylonian Date	Time (UT)	Event	Comments
			1197	*-739 June 30*	*5 Month IV*	*19:49*	*Summer Solstice*	
			1197	-739 June 30	5 Month IV	22:50	New Moon	
	41	30	1212	**-739 July 15**	**20 Month IV**	**06:52**	**Full Moon**	
			1227	-739 July 30	5 Month V	13:33	New Moon	
	42	30	1241	**-739 Aug. 13**	**19 Month V**	**15:38**	**Full Moon**	
			1257	-739 Aug. 29	5 Month VI	03:48	New Moon	
	43	30	1271	**-739 Sep. 12**	**19 Month VI**	**03:07**	**Lunar Eclipse**	Partial
			1286	-739 Sep. 27	4 Month VII	17:18	New Moon	
			1289	*-739 Sep. 30*	*7 Month VII*	*16:17*	*Autumnal Equinox*	
4	44	30	1300	**-739 Oct. 11**	**18 Month VII**	**17:43**	**Full Moon**	
			1316	-739 Oct. 27	4 Month VIII	05:48	New Moon	
	45	30	1330	**-739 Nov. 10**	**18 Month VIII**	**11:03**	**Full Moon**	
			1345	-739 Nov. 25	3 Month IX	17:14	New Moon	
	46	30	1360	**-739 Dec. 10**	**18 Month IX**	**06:03**	**Full Moon**	
			1375	-739 Dec. 25	3 Month X	03:49	New Moon	
			1378	*-739 Dec. 28*	*6 Month X*	*03:45*	*Winter Solstice*	
	47	30	1390	**-738 Jan. 9**	**18 Month X**	**01:20**	**Full Moon**	
			1404	-738 Jan. 23	2 Month XI	13:57	New Moon	
	48	30	1419	**-738 Feb. 7**	**17 Month XI**	**19:25**	**Full Moon**	
			1434	-738 Feb. 22	2 Month XII	00:00	New Moon	
	49	30	1449	**-738 Mar. 9**	**17 Month XII**	**11:01**	**Lunar Eclipse**	Not visible
			1463	-738 Mar. 23	1 Month I	10:27	New Moon	
			1468	*-738 Mar. 28*	*6 Month I*	*21:00*	*Vernal Equinox*	
5	50	29	1478	**-738 Apr. 7**	**16 Month I**	**23:31**	**Full Moon**	
			1492	-738 Apr. 21	1 Month II	21:33	New Moon	
	51	29	1508	**-738 May 7**	**17 Month II**	**09:09**	**Full Moon**	
			1522	-738 May 21	2 Month III	09:45	New Moon	
	52	29	1537	**-738 June 5**	**17 Month III**	**16:50**	**Full Moon**	
			1551	-738 June 19	2 Month IV	23:26	New Moon	
			1563	*-738 July 1*	*14 Month IV*	*01:41*	*Summer Solstice*	
	53	29	1566	**-738 July 4**	**17 Month IV**	**23:47**	**Full Moon**	
			1581	-738 July 19	3 Month V	14:46	New Moon	
	54	29	1596	**-738 Aug. 3**	**18 Month V**	**07:14**	**Full Moon**	
			1611	-738 Aug. 18	4 Month VI	07:19	New Moon	
	55	29	1625	**-738 Sep. 1**	**18 Month VI**	**16:06**	**Lunar Eclipse**	Total
			1641	-738 Sep. 17	5 Month VI_2	00:00	New Moon	
			1654	*-738 Sep. 30*	*18 Month* VI_2	*22:11*	*Autumnal Equinox*	
	56	30	1655	**-738 Oct. 1**	**19 Month** VI_2	**02:57**	**Full Moon**	
			1670	-738 Oct. 16	4 Month VII	16:02	New Moon	
5	57	29	1684	**-738 Oct. 30**	**18 Month VII**	**16:03**	**Full Moon**	
			1700	-738 Nov. 15	5 Month VIII	06:20	New Moon	
	58	29	1714	**-738 Nov. 29**	**19 Month VIII**	**07:26**	**Full Moon**	
			1729	-738 Dec. 14	5 Month IX	18:54	New Moon	
			1743	*-738 Dec. 28*	*19 Month IX*	*09:33*	*Winter Solstice*	
	59	29	1744	**-738 Dec. 29**	**20 Month IX**	**00:02**	**Full Moon**	
			1759	-737 Jan. 13	6 Month X	06:00	New Moon	
	60	29	1773	**-737 Jan. 27**	**20 Month X**	**19:23**	**Full Moon**	

CY	SM	ML	LC	Julian Date	Babylonian Date	Time (UT)	Event	Comments
			1788	-737 Feb. 11	6 Month XI	15:54	New Moon	
	61	29	1803	**-737 Feb. 26**	**21 Month XI**	**13:34**	**Lunar Eclipse**	Not visible
			1818	-737 Mar. 13	7 Month XII	00:02	New Moon	
	62	29	1833	**-737 Mar. 28**	**22 Month XII**	**05:48**	**Full Moon**	
			1834	*-737 Mar. 29*	*23 Month XII*	*02:47*	*Vernal Equinox*	
			1847	-737 Apr. 11	7 Month I	09:13	New Moon	
6	63	30	1862	**-737 Apr. 26**	**22 Month I**	**19:18**	**Full Moon**	
			1876	-737 May 10	6 Month II	17:56	New Moon	
	64	30	1892	**-737 May 26**	**22 Month II**	**06:16**	**Full Moon**	
			1906	-737 June 9	6 Month III	04:00	New Moon	
	65	30	1921	**-737 June 24**	**21 Month III**	**15:31**	**Full Moon**	
			1928	*-737 July 1*	*28 Month III*	*07:41*	*Summer Solstice*	
			1935	-737 July 8	5 Month IV	16:22	New Moon	
	66	30	1951	**-737 July 24**	**21 Month IV**	**00:00**	**Full Moon**	
			1965	-737 Aug. 7	5 Month V	07:27	New Moon	
	67	30	1980	**-737 Aug. 22**	**20 Month V**	**08:35**	**Lunar Eclipse**	Not visible
			1995	-737 Sep. 6	5 Month VI	00:02	New Moon	
	68	30	2009	**-737 Sep. 20**	**19 Month VI**	**17:48**	**Full Moon**	
			2020	*-737 Oct. 1*	*30 Month VI*	*04:07*	*Autumnal Equinox*	
			2024	-737 Oct. 5	4 Month VII	19:06	New Moon	
6	69	30	2039	**-737 Oct. 20**	**19 Month VII**	**04:05**	**Full Moon**	
			2054	-737 Nov. 4	4 Month VIII	12:59	New Moon	
	70	30	2068	**-737 Nov. 18**	**18 Month VIII**	**15:50**	**Full Moon**	
			2084	-737 Dec. 4	4 Month IX	05:23	New Moon	
	71	30	2098	**-737 Dec. 18**	**18 Month IX**	**05:27**	**Full Moon**	
			2108	*-737 Dec. 28*	*28 Month IX*	*15:27*	*Winter Solstice*	
			2113	-736 Jan. 2	3 Month X	19:44	New Moon	
	72	30	2127	**-736 Jan. 16**	**17 Month X**	**20:56**	**Lunar Eclipse**	Not visible
			2143	-736 Feb. 1	3 Month XI	07:47	New Moon	
	73	30	2157	**-736 Feb. 15**	**17 Month XI**	**13:38**	**Full Moon**	
			2172	-736 Mar. 1	2 Month XII	17:33	New Moon	
	74	30	2187	**-736 Mar. 16**	**17 Month XII**	**06:28**	**Full Moon**	
			2199	*-736 Mar. 28*	*29 Month XII*	*08:42*	*Vernal Equinox*	
			2202	-736 Mar. 31	2 Month I	01:30	New Moon	
7	75	29	2216	**-736 Apr. 14**	**16 Month I**	**22:23**	**Full Moon**	
			2231	-736 Apr. 29	2 Month II	08:30	New Moon	
	76	29	2246	**-736 May 14**	**17 Month II**	**12:50**	**Full Moon**	
			2260	-736 May 28	2 Month III	15:45	New Moon	
	77	29	2276	**-736 June 13**	**18 Month III**	**01:45**	**Full Moon**	
			2290	-736 June 27	3 Month IV	00:01	New Moon	
			2293	*-736 June 30*	*6 Month IV*	*13:28*	*Summer Solstice*	
	78	29	2305	**-736 July 12**	**18 Month IV**	**13:21**	**Lunar Eclipse**	Not visible
			2319	-736 July 26	3 Month V	11:39	New Moon	
	79	29	2334	**-736 Aug. 10**	**18 Month V**	**23:56**	**Lunar Eclipse**	Not visible
			2349	-736 Aug. 25	4 Month VI	01:43	New Moon	
	80	29	2364	**-736 Sep. 9**	**19 Month VI**	**09:53**	**Full Moon**	
			2378	-736 Sep. 23	4 Month VII	18:32	New Moon	

CY	SM	ML	LC	Julian Date	Babylonian Date	Time (UT)	Event	Comments
			2385	*-736 Sep. 30*	*11 Month VII*	*09:47*	*Autumnal Equinox*	
7	81	29	2393	**-736 Oct. 8**	**19 Month VII**	**19:42**	**Full Moon**	
			2408	-736 Oct. 23	5 Month VIII	13:14	New Moon	
	82	29	2423	**-736 Nov. 7**	**20 Month VIII**	**05:58**	**Full Moon**	
			2438	-736 Nov. 22	6 Month IX	08:36	New Moon	
	83	29	2452	**-736 Dec. 6**	**20 Month IX**	**17:07**	**Full Moon**	
			2468	-736 Dec. 22	7 Month X	03:03	New Moon	
			2473	*-736 Dec. 27*	*12 Month X*	*21:11*	*Winter Solstice*	
	84	**30**	2482	**-735 Jan. 5**	**21 Month X**	**05:21**	**Lunar Eclipse**	Not visible
			2497	-735 Jan. 20	6 Month XI	19:08	New Moon	**Extra Day**
	85	29	2511	**-735 Feb. 3**	**20 Month XI**	**18:33**	**Full Moon**	
			2527	-735 Feb. 19	7 Month XII	08:03	New Moon	
	86	**30**	2541	**-735 Mar. 5**	**21 Month XII**	**08:30**	**Full Moon**	
			2556	-735 Mar. 20	6 Month XII_2	17:55	New Moon	**Extra Day**
			2564	*-735 Mar. 28*	*14 Month* XII_2	*14:30*	*Vernal Equinox*	
	87	30	2570	**-735 Apr. 3**	**20 Month** $\mathbf{XII_2}$	**23:00**	**Full Moon**	
			2586	-735 Apr. 19	6 Month I	01:36	New Moon	
8	88	30	2600	**-735 May 3**	**20 Month I**	**13:56**	**Full Moon**	
			2615	-735 May 18	5 Month II	08:18	New Moon	
	89	30	2630	**-735 June 2**	**20 Month II**	**05:02**	**Full Moon**	
			2644	-735 June 16	4 Month III	15:10	New Moon	
			2658	*-735 June 30*	*18 Month III*	*19:19*	*Summer Solstice*	
	90	30	2659	**-735 July 1**	**19 Month III**	**19:52**	**Lunar Eclipse**	Total
			2673	-735 July 15	3 Month IV	23:12	New Moon	
	91	30	2689	**-735 July 31**	**19 Month IV**	**09:49**	**Full Moon**	
			2703	-735 Aug. 14	3 Month V	09:12	New Moon	
	92	30	2718	**-735 Aug. 29**	**18 Month V**	**22:35**	**Full Moon**	
			2732	-735 Sep. 12	2 Month VI	21:48	New Moon	
	93	30	2748	**-735 Sep. 28**	**18 Month VI**	**10:20**	**Full Moon**	
			2750	*-735 Sep. 30*	*20 Month VI*	*15:44*	*Autumnal Equinox*	
			2762	-735 Oct. 12	2 Month VII	13:20	New Moon	
8	94	30	2777	**-735 Oct. 27**	**17 Month VII**	**21:31**	**Full Moon**	
			2792	-735 Nov. 11	2 Month VIII	07:39	New Moon	
	95	30	2807	**-735 Nov. 26**	**17 Month VIII**	**08:34**	**Full Moon**	
			2822	-735 Dec. 11	2 Month IX	03:35	New Moon	
	96	30	2836	**-735 Dec. 25**	**16 Month IX**	**19:35**	**Lunar Eclipse**	Total
			2839	*-735 Dec. 28*	*19 Month IX*	*03:03*	*Winter Solstice*	
			2851	-734 Jan. 9	1 Month X	23:05	New Moon	
	97	30	2866	**-734 Jan. 24**	**16 Month X**	**06:27**	**Full Moon**	
			2881	-734 Feb. 8	1 Month XI	16:11	New Moon	
	98	30	2895	**-734 Feb. 22**	**15 Month XI**	**17:12**	**Full Moon**	
			2911	-734 Mar. 10	1 Month XII	05:58	New Moon	
	99	30	2925	**-734 Mar. 24**	**15 Month XII**	**04:17**	**Full Moon**	
			2929	*-734 Mar. 28*	*19 Month XII*	*20:14*	*Vernal Equinox*	
			2940	-734 Apr. 8	30 Month XII	16:40	New Moon	
1	1	29	2954	**-734 Apr. 22**	**14 Month I**	**16:23**	**Full Moon**	
			2970	-734 May 8	1 Month II	01:12	New Moon	

CY	SM	ML	LC	Julian Date	Babylonian Date	Time (UT)	Event	Comments
	2	29	2984	**-734 May 22**	**15 Month II**	**05:57**	**Full Moon**	
			2999	-734 June 6	1 Month III	08:34	New Moon	
	3	29	3013	**-734 June 20**	**15 Month III**	**20:57**	**Lunar Eclipse**	Total
			3024	*-734 July 1*	*26 Month III*	*01:03*	*Summer Solstice*	
			3028	-734 July 5	1 Month IV	15:40	New Moon	
	4	29	3043	**-734 July 20**	**16 Month IV**	**12:45**	**Full Moon**	
			3057	-734 Aug. 3	1 Month V	23:20	New Moon	
	5	29	3073	**-734 Aug. 19**	**17 Month V**	**04:32**	**Full Moon**	
			3087	-734 Sep. 2	2 Month VI	08:25	New Moon	
	6	29	3102	**-734 Sep. 17**	**17 Month VI**	**19:40**	**Full Moon**	
			3115	*-734 Sep. 30*	*1 Month VII*	*21:37*	*Autumnal Equinox*	
			3116	-734 Oct. 1	2 Month VII	19:48	New Moon	
1	7	29	3132	**-734 Oct. 17**	**18 Month VII**	**09:55**	**Full Moon**	
			3146	-734 Oct. 31	3 Month VIII	10:08	New Moon	
	8	29	3161	**-734 Nov. 15**	**18 Month VIII**	**23:12**	**Full Moon**	
			3176	-734 Nov. 30	4 Month IX	03:22	New Moon	
	9	29	3191	**-734 Dec. 15**	**19 Month IX**	**11:22**	**Lunar Eclipse**	Not visible
			3204	*-734 Dec. 28*	*3 Month X*	*08:52*	*Winter Solstice*	
			3205	-734 Dec. 29	4 Month X	22:24	New Moon	
	10	29	3220	**-733 Jan. 13**	**19 Month X**	**22:10**	**Full Moon**	
			3235	-733 Jan. 28	5 Month XI	17:23	New Moon	
	11	29	3250	**-733 Feb. 12**	**20 Month XI**	**07:42**	**Full Moon**	
			3265	-733 Feb. 27	6 Month XII	10:43	New Moon	
	12	29	3279	**-733 Mar. 13**	**20 Month XII**	**16:30**	**Full Moon**	
			3295	-733 Mar. 29	7 Month I	01:34	New Moon	
			3295	*-733 Mar. 29*	*7 Month I*	*01:59*	*Vernal Equinox*	
2	13	30	3309	**-733 Apr. 12**	**21 Month I**	**01:30**	**Full Moon**	
			3324	-733 Apr. 27	6 Month II	13:53	New Moon	
	14	30	3338	**-733 May 11**	**20 Month II**	**11:36**	**Full Moon**	
			3353	-733 May 26	5 Month III	23:59	New Moon	
	15	30	3367	**-733 June 9**	**19 Month III**	**23:30**	**Lunar Eclipse**	Not visible
			3383	-733 June 25	5 Month IV	08:30	New Moon	
			3389	*-733 July 1*	*11 Month IV*	*06:49*	*Summer Solstice*	
	16	30	3397	**-733 July 9**	**19 Month IV**	**13:23**	**Full Moon**	
			3412	-733 July 24	4 Month V	16:12	New Moon	
	17	30	3427	**-733 Aug. 8**	**19 Month V**	**05:04**	**Full Moon**	
			3442	-733 Aug. 23	4 Month VI	00:00	New Moon	
	18	30	3456	**-733 Sep. 6**	**18 Month VI**	**22:03**	**Full Moon**	
			3471	-733 Sep. 21	3 Month VI$_2$	09:02	New Moon	
			3481	*-733 Oct. 1*	*13 Month VI*$_2$	*03:24*	*Autumnal Equinox*	
	19	30	3486	**-733 Oct. 6**	**18 Month VI**$_2$	**15:34**	**Full Moon**	
			3500	-733 Oct. 20	2 Month VII	19:58	New Moon	
2	20	30	3516	**-733 Nov. 5**	**18 Month VII**	**08:36**	**Lunar Eclipse**	Not visible
			3530	-733 Nov. 19	2 Month VIII	09:15	New Moon	
	21	30	3546	**-733 Dec. 5**	**18 Month VIII**	**00:00**	**Full Moon**	
			3560	-733 Dec. 19	2 Month IX	00:02	New Moon	
			3569	*-733 Dec. 28*	*11 Month IX*	*14:34*	*Winter Solstice*	

CY	SM	ML	LC	Julian Date	Babylonian Date	Time (UT)	Event	Comments
	22	30	3575	**-732 Jan. 3**	**17 Month IX**	**13:09**	**Full Moon**	
			3589	-732 Jan. 17	1 Month X	17:24	New Moon	
	23	30	3604	**-732 Feb. 1**	**16 Month X**	**23:51**	**Full Moon**	
			3619	-732 Feb. 16	1 Month XI	10:40	New Moon	
	24	30	3634	**-732 Mar. 2**	**16 Month XI**	**08:43**	**Full Moon**	
			3649	-732 Mar. 17	1 Month XII	03:36	New Moon	
			3660	*-732 Mar. 28*	*12 Month XII*	*07:46*	*Vernal Equinox*	
	25	30	3663	**-732 Mar. 31**	**15 Month XII**	**16:35**	**Full Moon**	
			3678	-732 Apr. 15	30 Month XII	19:22	New Moon	
3	26	29	3693	**-732 Apr. 30**	**15 Month I**	**00:01**	**Lunar Eclipse**	Partial
			3708	-732 May 15	1 Month II	09:19	New Moon	
	27	29	3722	**-732 May 29**	**15 Month II**	**08:52**	**Full Moon**	
			3737	-732 June 13	1 Month III	21:09	New Moon	
	28	29	3751	**-732 June 27**	**15 Month III**	**18:52**	**Full Moon**	
			3754	*-732 June 30*	*18 Month III*	*12:43*	*Summer Solstice*	
			3767	-732 July 13	2 Month IV	07:11	New Moon	
	29	29	3781	**-732 July 27**	**16 Month IV**	**07:04**	**Full Moon**	
			3796	-732 Aug. 11	2 Month V	16:12	New Moon	
	30	29	3810	**-732 Aug. 25**	**16 Month V**	**21:58**	**Full Moon**	
			3826	-732 Sep. 10	3 Month VI	01:12	New Moon	
	31	29	3840	**-732 Sep. 24**	**17 Month VI**	**15:33**	**Full Moon**	
			3846	*-732 Sep. 30*	*23 Month VI*	*09:18*	*Autumnal Equinox*	
			3855	-732 Oct. 9	3 Month VII	11:00	New Moon	
3	32	29	3870	**-732 Oct. 24**	**18 Month VII**	**10:49**	**Lunar Eclipse**	Not visible
			3884	-732 Nov. 7	3 Month VIII	21:57	New Moon	
	33	29	3900	**-732 Nov. 23**	**19 Month VIII**	**05:53**	**Full Moon**	
			3914	-732 Dec. 7	4 Month IX	10:01	New Moon	
	34	29	3929	**-732 Dec. 22**	**19 Month IX**	**22:56**	**Full Moon**	
			3934	*-732 Dec. 27*	*24 Month IX*	*20:33*	*Winter Solstice*	
			3943	-731 Jan. 5	4 Month X	23:04	New Moon	
	35	29	3959	**-731 Jan. 21**	**20 Month X**	**13:04**	**Full Moon**	
			3973	-731 Feb. 4	5 Month XI	13:06	New Moon	
	36	29	3989	**-731 Feb. 20**	**21 Month XI**	**00:01**	**Full Moon**	
			4003	-731 Mar. 6	6 Month XII	04:11	New Moon	
	37	29	4018	**-731 Mar. 21**	**21 Month XII**	**09:32**	**Full Moon**	
			4025	*-731 Mar. 28*	*28 Month XII*	*13:36*	*Vernal Equinox*	
			4032	-731 Apr. 4	6 Month I	20:01	New Moon	
4	38	30	4047	**-731 Apr. 19**	**21 Month I**	**17:15**	**Lunar Eclipse**	Total
			4062	-731 May 4	6 Month II	11:49	New Moon	
	39	30	4077	**-731 May 19**	**21 Month II**	**00:01**	**Full Moon**	
			4092	-731 June 3	6 Month III	02:43	New Moon	
	40	30	4106	**-731 June 17**	**20 Month III**	**07:31**	**Full Moon**	
			4119	*-731 June 30*	*3 Month IV*	*18:20*	*Summer Solstice*	
			4121	-731 July 2	5 Month IV	16:13	New Moon	
	41	30	4135	**-731 July 16**	**19 Month IV**	**15:58**	**Full Moon**	
			4151	-731 Aug. 1	5 Month V	04:23	New Moon	
	42	30	4165	**-731 Aug. 15**	**19 Month V**	**02:45**	**Full Moon**	

CY	SM	ML	LC	Julian Date	Babylonian Date	Time (UT)	Event	Comments
			4180	-731 Aug. 30	4 Month VI	15:44	New Moon	
	43	30	4194	**-731 Sep. 13**	**18 Month VI**	**16:47**	**Full Moon**	
			4210	-731 Sep. 29	4 Month VII	02:46	New Moon	
			4211	*-731 Sep. 30*	*5 Month VII*	*14:57*	*Autumnal Equinox*	
4	44	30	4224	**-731 Oct. 13**	**18 Month VII**	**10:08**	**Lunar Eclipse**	Not visible
			4239	-731 Oct. 28	3 Month VIII	13:44	New Moon	
	45	30	4254	**-731 Nov. 12**	**18 Month VIII**	**05:39**	**Full Moon**	
			4269	-731 Nov. 27	3 Month IX	00:02	New Moon	
	46	30	4284	**-731 Dec. 12**	**18 Month IX**	**01:24**	**Full Moon**	
			4298	-731 Dec. 26	2 Month X	11:28	New Moon	
			4300	*-731 Dec. 28*	*4 Month X*	*02:23*	*Winter Solstice*	
	47	30	4313	**-730 Jan. 10**	**17 Month X**	**19:33**	**Full Moon**	
			4327	-730 Jan. 24	1 Month XI	22:30	New Moon	
	48	30	4343	**-730 Feb. 9**	**17 Month XI**	**11:05**	**Full Moon**	
			4357	-730 Feb. 23	1 Month XII	10:14	New Moon	
	49	30	4372	**-730 Mar. 10**	**16 Month XII**	**23:44**	**Full Moon**	
			4386	-730 Mar. 24	30 Month XII	23:02	New Moon	
			4390	*-730 Mar. 28*	*4 Month I*	*19:18*	*Vernal Equinox*	
5	50	29	4402	**-730 Apr. 9**	**16 Month I**	**09:43**	**Lunar Eclipse**	Not visible
			4416	-730 Apr. 23	1 Month II	12:55	New Moon	
	51	29	4431	**-730 May 8**	**16 Month II**	**17:37**	**Full Moon**	
			4446	-730 May 23	2 Month III	03:34	New Moon	
	52	29	4461	**-730 June 7**	**17 Month III**	**00:01**	**Full Moon**	
			4475	-730 June 21	2 Month IV	18:34	New Moon	
			4485	*-730 July 1*	*12 Month IV*	*00:00*	*Summer Solstice*	
	53	29	4490	**-730 July 6**	**17 Month IV**	**06:58**	**Full Moon**	
			4505	-730 July 21	3 Month V	09:36	New Moon	
	54	29	4519	**-730 Aug. 4**	**17 Month V**	**14:48**	**Full Moon**	
			4535	-730 Aug. 20	4 Month VI	00:01	New Moon	
	55	29	4549	**-730 Sep. 3**	**18 Month VI**	**00:02**	**Full Moon**	
			4564	-730 Sep. 18	4 Month VI_2	14:37	New Moon	
			4576	*-730 Sep. 30*	*16 Month* VI_2	*20:45*	*Autumnal Equinox*	
	56	30	4578	**-730 Oct. 2**	**18 Month** VI_2	**14:05**	**Lunar Eclipse**	Partial
			4594	-730 Oct. 18	4 Month VII	03:55	New Moon	
5	57	29	4608	**-730 Nov. 1**	**18 Month VII**	**06:11**	**Full Moon**	
			4623	-730 Nov. 16	4 Month VIII	16:02	New Moon	
	58	29	4638	**-730 Dec. 1**	**19 Month VIII**	**00:01**	**Full Moon**	
			4653	-730 Dec. 16	5 Month IX	03:02	New Moon	
			4665	*-730 Dec. 28*	*17 Month IX*	*08:07*	*Winter Solstice*	
	59	29	4667	**-730 Dec. 30**	**19 Month IX**	**19:42**	**Full Moon**	
			4682	-729 Jan. 14	5 Month X	13:14	New Moon	
	60	29	4697	**-729 Jan. 29**	**20 Month X**	**14:26**	**Full Moon**	
			4711	-729 Feb. 12	5 Month XI	23:05	New Moon	
	61	29	4727	**-729 Feb. 28**	**21 Month XI**	**07:16**	**Lunar Eclipse**	Not visible
			4741	-729 Mar. 14	6 Month XII	09:02	New Moon	
			4756	*-729 Mar. 29*	*21 Month XII*	*01:04*	*Vernal Equinox*	
	62	29	4756	**-729 Mar. 29**	**21 Month XII**	**21:16**	**Full Moon**	

CY	SM	ML	LC	Julian Date	Babylonian Date	Time (UT)	Event	Comments
			4770	-729 Apr. 12	6 Month I	19:28	New Moon	
6	63	30	4786	**-729 Apr. 28**	**22 Month I**	**08:14**	**Full Moon**	
			4800	-729 May 12	6 Month II	06:51	New Moon	
	64	30	4815	**-729 May 27**	**21 Month II**	**16:47**	**Full Moon**	
			4829	-729 June 10	5 Month III	19:38	New Moon	
	65	30	4845	**-729 June 26**	**21 Month III**	**00:00**	**Full Moon**	
			4850	*-729 July 1*	*26 Month III*	*05:56*	*Summer Solstice*	
			4859	-729 July 10	5 Month IV	10:10	New Moon	
	66	30	4874	**-729 July 25**	**20 Month IV**	**07:14**	**Full Moon**	
			4889	-729 Aug. 9	5 Month V	02:21	New Moon	
	67	30	4903	**-729 Aug. 23**	**19 Month V**	**15:28**	**Lunar Eclipse**	Not visible
			4918	-729 Sep. 7	4 Month VI	19:27	New Moon	
	68	30	4933	**-729 Sep. 22**	**19 Month VI**	**01:25**	**Lunar Eclipse**	Not visible
			4942	*-729 Oct. 1*	*28 Month VI*	*02:39*	*Autumnal Equinox*	
			4948	-729 Oct. 7	4 Month VII	12:14	New Moon	
6	69	30	4962	**-729 Oct. 21**	**18 Month VII**	**13:27**	**Full Moon**	
			4978	-729 Nov. 6	4 Month VIII	03:38	New Moon	
	70	30	4992	**-729 Nov. 20**	**18 Month VIII**	**03:41**	**Full Moon**	
			5007	-729 Dec. 5	3 Month IX	17:10	New Moon	
	71	30	5021	**-729 Dec. 19**	**17 Month IX**	**20:00**	**Full Moon**	
			5030	*-729 Dec. 28*	*26 Month IX*	*13:58*	*Winter Solstice*	
			5037	-728 Jan. 4	3 Month X	04:58	New Moon	
	72	30	5051	**-728 Jan. 18**	**17 Month X**	**13:55**	**Full Moon**	
			5066	-728 Feb. 2	2 Month XI	15:18	New Moon	
	73	30	5081	**-728 Feb. 17**	**17 Month XI**	**08:16**	**Lunar Eclipse**	Not visible
			5096	-728 Mar. 3	2 Month XII	00:01	New Moon	
	74	30	5111	**-728 Mar. 18**	**17 Month XII**	**01:27**	**Full Moon**	
			5121	*-728 Mar. 28*	*27 Month XII*	*07:00*	*Vernal Equinox*	
			5125	-728 Apr. 1	1 Month I	08:51	New Moon	
7	75	29	5140	**-728 Apr. 16**	**16 Month I**	**16:17**	**Full Moon**	
			5154	-728 Apr. 30	1 Month II	17:06	New Moon	
	76	29	5170	**-728 May 16**	**17 Month II**	**04:29**	**Full Moon**	
			5184	-728 May 30	2 Month III	02:12	New Moon	
	77	29	5199	**-728 June 14**	**17 Month III**	**14:35**	**Full Moon**	
			5213	-728 June 28	2 Month IV	13:15	New Moon	
			5215	*-728 June 30*	*4 Month IV*	*11:38*	*Summer Solstice*	
	78	29	5228	**-728 July 13**	**17 Month IV**	**23:31**	**Full Moon**	
			5243	-728 July 28	3 Month V	03:00	New Moon	
	79	29	5258	**-728 Aug. 12**	**18 Month V**	**08:11**	**Lunar Eclipse**	Not visible
			5272	-728 Aug. 26	3 Month VI	19:28	New Moon	
	80	29	5287	**-728 Sep. 10**	**18 Month VI**	**17:14**	**Full Moon**	
			5302	-728 Sep. 25	4 Month VII	13:42	New Moon	
			5307	*-728 Sep. 30*	*9 Month VII*	*08:16*	*Autumnal Equinox*	
7	81	29	5317	**-728 Oct. 10**	**19 Month VII**	**03:06**	**Full Moon**	
			5332	-728 Oct. 25	5 Month VIII	08:11	New Moon	
	82	29	5346	**-728 Nov. 8**	**19 Month VIII**	**14:08**	**Full Moon**	
			5362	-728 Nov. 24	6 Month IX	01:35	New Moon	

CY	SM	ML	LC	Julian Date	Babylonian Date	Time (UT)	Event	Comments
	83	29	5376	**-728 Dec. 8**	**20 Month IX**	**02:43**	**Full Moon**	
			5391	-728 Dec. 23	6 Month X	17:05	New Moon	
			5395	*-728 Dec. 27*	*10 Month X*	*19:40*	*Winter Solstice*	
	84	29	5405	**-727 Jan. 6**	**20 Month X**	**17:06**	**Full Moon**	
			5421	-727 Jan. 22	7 Month XI	06:15	New Moon	
	85	**30**	5435	**-727 Feb. 5**	**21 Month XI**	**09:01**	**Lunar Eclipse**	Not visible
			5450	-727 Feb. 20	6 Month XII	17:00	New Moon	**Extra Day**
	86	29	5465	**-727 Mar. 7**	**21 Month XII**	**01:38**	**Full Moon**	
			5480	-727 Mar. 22	7 Month I	01:37	New Moon	
			5486	*-727 Mar. 28*	*13 Month I*	*12:47*	*Vernal Equinox*	
8	87	30	5494	**-727 Apr. 5**	**21 Month I**	**17:54**	**Full Moon**	
			5509	-727 Apr. 20	6 Month II	08:49	New Moon	
	88	30	5524	**-727 May 5**	**21 Month II**	**09:02**	**Full Moon**	
			5538	-727 May 19	5 Month III	15:41	New Moon	
	89	30	5553	**-727 June 3**	**20 Month III**	**22:46**	**Full Moon**	
			5567	-727 June 17	4 Month IV	23:28	New Moon	
			5580	*-727 June 30*	*17 Month IV*	*17:25*	*Summer Solstice*	
	90	30	5583	**-727 July 3**	**20 Month IV**	**11:11**	**Full Moon**	
			5597	-727 July 17	4 Month V	09:19	New Moon	
	91	30	5612	**-727 Aug. 1**	**19 Month V**	**22:29**	**Lunar Eclipse**	Total
			5626	-727 Aug. 15	3 Month VI	21:59	New Moon	
	92	30	5642	**-727 Aug. 31**	**19 Month VI**	**08:58**	**Full Moon**	
			5656	-727 Sep. 14	3 Month VI_2	13:35	New Moon	
	93	30	5671	**-727 Sep. 29**	**18 Month VI_2**	**19:01**	**Full Moon**	
			5672	*-727 Sep. 30*	*19 Month VI_2*	*14:07*	*Autumnal Equinox*	
			5686	-727 Oct. 14	3 Month VII	07:36	New Moon	
8	94	30	5701	**-727 Oct. 29**	**18 Month VII**	**05:09**	**Full Moon**	
			5716	-727 Nov. 13	3 Month VIII	02:56	New Moon	
	95	30	5730	**-727 Nov. 27**	**17 Month VIII**	**15:51**	**Full Moon**	
			5745	-727 Dec. 12	2 Month IX	22:06	New Moon	
	96	30	5760	**-727 Dec. 27**	**17 Month IX**	**03:26**	**Full Moon**	
			5761	*-727 Dec. 28*	*18 Month IX*	*01:31*	*Winter Solstice*	
			5775	-726 Jan. 11	2 Month X	15:31	New Moon	
	97	30	5789	**-726 Jan. 25**	**16 Month X**	**15:57**	**Lunar Eclipse**	Partial
			5805	-726 Feb. 10	2 Month XI	06:00	New Moon	
	98	30	5819	**-726 Feb. 24**	**16 Month XI**	**05:15**	**Full Moon**	
			5834	-726 Mar. 11	1 Month XII	17:13	New Moon	
	99	30	5848	**-726 Mar. 25**	**15 Month XII**	**19:10**	**Full Moon**	
			5851	*-726 Mar. 28*	*18 Month XII*	*18:30*	*Vernal Equinox*	
			5864	-726 Apr. 10	1 Month I	01:46	New Moon	