# Explaining Babylonian Astronomy

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**Abstract:** A large number of cuneiform tablets from ancient Babylonia containing astronomical texts are preserved. It is on the basis of these texts that we can attempt to reconstruct the history of Babylonian astronomical practice. In order to do so, the individual astronomical texts themselves must be understood. This essay discusses three different types of explanation of an astronomical text that are part of this process: a philological explanation, a technical explanation, and a historical explanation. It argues that a full understanding of any text can be achieved only once all three types of explanation have been provided.

The study of Babylonian astronomy, in common with that of most ancient and medieval sciences, presents the historian of science with a range of challenges that differ from those faced by historians working on more recent science. Our sources are limited in number, often fragmentary, written in a dead language, distributed unevenly over a fairly long time period, and usually the result of everyday astronomical practice rather than being either didactic or self-reflective texts that present the underlying basis of the astronomy and its development. Furthermore, while the Babylonians were looking at the same sky as us, they observed and understood it from their own cultural perspective within a conceptual framework that only partially overlaps with our own. How, then, do we go about explaining an aspect of Babylonian astronomy or, at a more basic level, the contents of a Babylonian astronomical text?

It seems to me that there are three stages, or three types, of explanation when dealing with a Babylonian astronomical text: a philological explanation, a technical explanation, and a historical explanation. First, the text must be studied using the basic tools of philology so that it can be "read" and translated into English or another modern language. This process is not as easy as it sounds because although the cuneiform writing system and the Akkadian language are well understood, scientific texts abound with technical terminology whose specific meaning can be determined only from the context, often by means of a detailed astronomical or mathematical analysis of the occasions on which the terminology is used. Any translation is an interpretation, but for scientific texts with specialist terminology this is even more the case, and it is essential, but not always easy, to produce a translation that is not simply a functional representation of the basic content of the original text but that also preserves the subtle distinctions in terminology for what may at first sight seem like the same operation—yet without the translation becoming so literal

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that it is in practice unreadable.[1] We must also try to avoid unconsciously imposing concepts from modern (or ancient Greek) astronomy on the text. Second, a full technical explanation of the contents of the text is required, one that offers a modern astronomical and mathematical understanding of the observations, calculations, or theories presented. Sometimes this will involve comparison with modern retrocalculated data in order to analyze the accuracy of the ancient observations and calculations. By studying the types of "errors" in the ancient data, it is sometimes possible to understand better the methods by which observations and calculations were made. Finally, a historical explanation seeks to understand the text within the history of both Babylonian astronomy and Babylonian scholarship as a whole and its cultural context. These three stages of explanation are, of course, not strictly separate, and in practice a full explanation is reached through several iterations back and forth between these three stages.

In order to illustrate this process, I will discuss two texts that relate to what in modern astronomy is called the problem of oblique ascension or the rising times of stretches of the ecliptic.[2] Because the Earth's axis of rotation is tilted by roughly 23° from perpendicular to the plane of the Earth's orbit around the Sun, the length of the stretch of the celestial equator that rises over the eastern horizon as a fixed length of the ecliptic rises depends on which part of the ecliptic is rising. Thus, for example, at Babylon, roughly twice the length of the celestial equator will rise (or culminate at the meridian) during the time it takes the zodiacal sign Virgo to rise as during the time it takes Pisces to rise. A scheme giving the rising time for each sign of the zodiac can be used to determine the length of day and night by adding up the rising times corresponding to 180° of the ecliptic beginning with the point that is rising at sunrise or sunset, and indeed Otto Neugebauer showed that just such a method was employed in the so-called System A and System B lunar theories of Late Babylonian mathematical astronomy.[3]

Let us now examine our first text. The text is known from two copies, both of which are written on cuneiform tablets (BM 34639 and BM 38704) from Babylon that probably date to sometime in the last four centuries B.C.E. I present below a transliteration of part of BM 34639.[4] Partially preserved cuneiform signs are enclosed within half brackets. Restored passages are given within square brackets and are based on either the duplicate or the symmetry of the scheme that the text presents.

*ina* ITU.DU$_6$ ⸢UD⸣.15 $^{d}$UTU ⸢*ina*⸣ [UGU MÚL *ku-mar šá* MÚL.UD.KA.DUḪ.A ŠÚ-*ma*] *ina* UGU 5 UŠ *ár* ⸢MÚL⸣.[AL.LUL KUR]

*ina* ITU.⸢APIN UD.15 $^{d}$UTU *ina* UGU⸣ [10 UŠ *ár* MÚL SA$_4$ *šá* GABA-*šú* ŠÚ-*ma*] *ina* UGU ⸢½ DANNA *ár* 4⸣ *šá* GABA-⸢*šú*⸣ [KUR]

*ina* ITU.GAN UD.15 $^{d}$UTU ⸢*ina* UGU⸣ 10 ⸢UŠ *ár*⸣ [MÚL.*kin-ṣi* ŠÚ-*ma*] *ina* UGU ½ DANNA *ár* ⸢MÚL.*e*$_4$-*ru*$_6$⸣ [KUR]

*ina* ITU.AB UD.15 $^{d}$UTU *ina* UGU ⸢4⸣ [*šá* MÚL.LU.LIM ŠÚ-*ma*] *ina muḫ-ḫi kip-pat* [KUR]

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[1] An important example of the need to preserve and study the subtle distinctions in terminology used in scientific cuneiform texts is Jens Høyrup's work on mathematical terminology, where he shows that the different terms used for simple mathematical operations such as multiplication and subtraction reflect an underlying geometrical layer of Babylonian mathematical thought. See, e.g., Jens Høyrup, *Lengths, Widths, Surfaces: A Portrait of Old Babylonian Algebra and Its Kin* (New York: Springer, 2002). For a discussion of the problems of translating Babylonian astronomical texts see Mathieu Ossendrijver, "Translating Babylonian Astronomical Diaries and Procedure Texts," in *Translating the Writings of Early Scholars in the Ancient Near East, Egypt, Greece, and Rome*, ed. Annette Imhausen and Tanja Pommerening (Berlin: De Gruyter, 2016), pp. 125–172.

[2] For a full discussion of these and related texts see John M. Steele, *Rising Time Schemes in Babylonian Astronomy* (Dordrecht: Springer, 2017).

[3] Otto Neugebauer, "Jahreszeiten und Tageslängen in der babylonischen Astronomie," *Osiris*, 1936, 2:517–550; and Neugebauer, "The Rising Times in Babylonian Astronomy," *Journal of Cuneiform Studies*, 1953, 7:100–102.

[4] BM 34639 Obv. II 5′–14′.

It is worth noting that even this transliteration of the text represents an interpretation of its contents, because a single sign in the cuneiform writing system can often be read as several different syllabic values and also as one or more different logograms standing for a complete word. In choosing how to transliterate the text, therefore, I am drawing not only on our knowledge of the Akkadian language and its grammar but also on my own experience reading astronomical texts written in cuneiform and an idea of what is a plausible reading of a particular sign in order for the text to make sense. Next, we can proceed to a translation of the text:

Month VII, day 15, the Sun [sets] at [the culmination of The Shoulder of the Panther and rises] at the culmination of 5 UŠ behind [The Crab].
Month VIII, day 15, the Sun [sets] at the culmination of [10 UŠ behind The Bright Star of its Chest and rises] at the culmination of ½ *bēru* behind The 4 Stars of his Breast.
Month IX, day 15, the Sun [sets] at the culmination of 10 UŠ behind [The Knee and rises] at the culmination of ½ *bēru* behind Eru.
Month X, day 15, the Sun [sets] at the culmination of The 4 (Stars) [of the Stag and rises] at the culmination of The Circle.

In this translation initial letters of the names of stars are capitalized. The stars are all taken from lists of so-called *ziqpu* stars—stars that culminate in a known order and at known intervals. The units *bēru* and UŠ are used for linear distances, time measurements, or, in this case, something like angular distances. One day, or one complete rotation of the celestial sphere, is equal to 12 *bēru* of time or, in modern terms, 12 *bēru* of right ascension, and there are 30 UŠ in one *bēru*. The text, then, presents a series of statements of either the culmination of a star or the culmination of a point given in *bēru* or UŠ behind a star at sunrise and sunset on the fifteenth day of each month of the year. We have therefore achieved the first type of explanation—we know what the text says.

Next we must provide a technical explanation of the material. The text itself does not indicate whether the statements of the culminating points at sunrise and sunset are based on observation or are schematic. However, because we have other texts that give the distances in *bēru* and UŠ between the *ziqpu* stars that appear in this text, we can determine how much the culminating point moves between each entry in the text. If we do this, we find that the culminating point at sunset changes by 20 UŠ per month in one half of the year and by 40 UŠ per month in the other half of the year. Similarly, the culminating point at sunrise changes by 20 UŠ per month for half of the year and 40 UŠ for the other half of the year, but the two halves of the year are opposite to those for the sunset entries. Thus, the text is clearly presenting a scheme rather than a series of observations. This conclusion is further supported by the fact that the dates given in the text are all the fifteenth of the month and that a full cycle of the *ziqpu* stars takes exactly twelve months, implying that the dates are given in the schematic 360-day calendar rather than the civil lunisolar calendar.

Before we turn to a historical explanation of this text, let us consider a second text that presents a different version of the same scheme, reformulated in terms of the signs of the zodiac rather the Sun's position at sunrise or sunset on given dates in the year. Here is a translation of one entry: "5 UŠ behind The Shoulder of the Panther culminates and the Sun ditto (at) the 9th portion of Aries (which) is Sagittarius of Aries (and corresponds to) Month IX rises. In Month IX, in the morning (which corresponds to) the 2[8(th day) M]ars expels a flare."[5]

This text is considerably more complex than the text discussed above. Each entry begins with a statement of the position at or behind a *ziqpu* star that culminates as a particular part of a zodiacal sign rises across the eastern horizon. The twelve 30° zodiacal signs are themselves divided into

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[5] BM 34713 Rev. I 20–21.

twelve 2.5° parts that are both numbered and named after the signs of the zodiac themselves. This entry concerns the ninth portion of the zodiacal sign Aries, which is named Sagittarius of Aries, and states that when the (end of the) sign rises, the point 5 UŠ behind the *ziqpu* star called the Shoulder of the Panther culminates. The text then adds a series of astrological associations that we need not discuss here.

We now come to the historical explanation of these tablets. The basic scheme presented in these two tablets is identical. But what was the purpose of these schemes and what is their place within Babylonian astronomy more generally? Johann Schaumberger, who first identified texts containing small parts of the zodiacal version of the scheme, assumed that they were related to the methods of computing the length of daylight in lunar System A and System B and so saw the texts as being part of mathematical astronomy. Francesca Rochberg, however, subsequently identified more texts containing further parts of the zodiac-based version of the scheme and showed that the scheme did not agree with System A or System B but instead agreed with a very simple linear zigzag function for the length of daylight. This daylight scheme is based on a very inaccurate ratio for the length of the longest to the shortest day and is attested in early texts such as MUL.APIN.[6] Rochberg maintained the assumption that the purpose of the scheme was to provide a means to determine the length of daylight.

Having identified also the calendar-based version of the scheme, however, I was able to provide what I think is a fuller explanation of the material. First, it is important to note that the texts are purely descriptive, written in the third person, with no second-person instructions of how to make calculations. Indeed, the texts make no reference to the length of day and night. Thus, it seems better to explain these texts as providing a description of an astronomical fact in the form of a simple scheme rather than as a tool for calculating day lengths. Second, it seems certain that the calendar-based version of the scheme is older and that the zodiac-based version was constructed from it simply by equating months with the corresponding zodiacal signs, a common technique in what I have elsewhere termed "schematic astronomy," a type of astronomy that uses simple mathematical functions such as zigzag functions with integer periods and that operates using the schematic 360-day calendar rather than the civil lunisolar calendar with twenty-nine- or thirty-day months and either twelve or thirteen months in the year, depending on intercalation.[7] The scheme in our texts uses the schematic calendar and places the dates of the solstices and equinoxes on the fifteenth day of Months I, IV, VII, and X, which is also typical of Babylonian schematic astronomy, and, as first recognized by Rochberg, the underlying scheme itself incorporates parameters from the schematic astronomical tradition. It thus seems certain that these texts should be understood as part of schematic astronomy rather than, as Schaumberger assumed, mathematical astronomy. Finally, and perhaps most importantly, these texts show that the schematic astronomical tradition was still a living tradition, interacting with new astronomical developments such as the invention of the zodiac, in the late period, whereas we might naively expect it to have been superseded by the much more complicated (and, from a modern perspective, "better") mathematical astronomy. Instead, these texts show that different astronomical traditions coexisted in Babylonia in the late period. This important historical explanation is possible only because of the philological and technical explanations of the texts that preceded it.

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[6] Johann Schaumberger, "Anaphora und Aufgangskalender in neuen *Ziqpu*-Texten," *Zeitschrift für Assyriologie*, 1955, 52:237–251; Francesca Rochberg, "A Babylonian Rising Time Scheme in Non-Tabular Astronomical Texts," in *Studies in the History of the Exact Sciences in Honour of David Pingree*, ed. Charles Burnett, Jan P. Hogendijk, Kim Plofker, and Michio Yano (Leiden: Brill, 2004), pp. 56–94; and Hermann Hunger and John Steele, *The Babylonian Astronomical Compendium MUL.APIN* (Abingdon, Oxfordshire: Routledge, 2019). MUL.APIN is an early Babylonian compendium of astronomical material.

[7] Steele, *Rising Time Schemes in Babylonian Astronomy* (cit. n. 2), pp. 10–12.