KUR – When the Old Moon Can Be Seen a Day Later

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Preface

It is our great pleasure to contribute this little paper to honor Alice Slotsky. We have chosen to write about the cuneiform tablet BM 37110. It is our greeting to a dear friend who is excited about all kinds of cuneiform writing. Indeed, Alice is the happy center of communication between scholars of the field.

Introduction

As Sachs was working on all types of astronomical cuneiform texts in the British Museum, he classified them as mathematical astronomical texts (now called ACT) and as non-mathematical astronomical types: Diaries, Almanacs, Normal Star Almanacs and Goal-Year Texts.[2] All fragments of tablets from the intermediate period which belonged neither to one of these categories nor to ACT material and which were difficult to understand were put away in a box. Our text BM 37110 was in that box until Christopher Walker drew our attention to the text, since it seemed to be connected to the so-called "Goal-Year Method" for the prediction of lunar phases. Indeed, BM 37110 is the first cuneiform tablet found so far, which is concerned with the Goal-Year method for the calculation of KUR, one of the six special time intervals, which, around new moon and full moon, were observed regularly by Babylonian astronomers.

The Lunar Six

At the end of the (synodic) Babylonian month, the event of KUR took place and could be measured:

KUR = time from last visible moonrise before conjunction to sunrise.

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2. Abraham Sachs, "A Classification of the Babylonian Astronomical Tablets of the Seleucid Period," *Journal of Cuneiform Studies* 2, no. 4 (1948): 271–290.

The time interval NA_N was observed on the evening when the new crescent was visible for the first time after conjunction, indicating the first day of the month. Thus,

NA_N = sunset to the first visible setting of the new moon.[3]

At sunrise and sunset in the days around opposition, i.e., in the middle of the Babylonian month, the following Lunar Four time intervals were regularly measured:

ŠÚ = moonset to sunrise of the last moonset before sunrise.
NA = sunrise to moonset of the first moonset after sunrise.
ME = moonrise to sunset of the last moonrise before sunset.
GE_6 = sunset to moonrise of the first moonrise after sunset.

ME and GE_6 were measured on two consecutive evenings, and their sum, ME+GE_6, tells how much time (with respect to sunset) the rising of the moon had been delayed from one evening to the next. Therefore we call ME+GE_6 the daily retardation of the rising moon. In spite of the fact that these time intervals—from a modern theoretical point of view—are very complicated quantities, the Babylonians succeeded in predicting them. They utilized the knowledge that a Saros, or 223 synodic months, was about $\frac{1}{3}$ of a day longer than an integer number (6585) of days. And, they must have noticed that ME+GE_6, the daily retardation of the rising moon, repeats after one Saros.

The Goal-Year Method for Predicting Lunar Six

A special type of astronomical cuneiform tablets, the Goal-Year Texts, presents raw materials for the prediction of planetary and lunar phenomena for a given year, called the "goal year."[4] A systematic analysis of the lunar data collected on Goal-Year tablets resulted in a proposal about how such data could have been used for predicting the Lunar Six time intervals, and the procedure text TU 11 indeed confirmed the proposal.[5]

The Goal-Year Method predicts all elements of the Lunar Six for a given month by means of two sets of Lunar Sixes, the first observed

3. In the texts with which we are working, this interval is called NA, but it always occurs with an indication that it is the NA of the first day or the NA at the beginning of the month. We put this identification into the name, calling it NA(of the new crescent), or NA_N. We have established this convention in order to be as precise as the Babylonian texts. There the term NA is also used for a time interval in the middle of the month, but it is always identified by calling it the NA of day 14 or the NA opposite the sun.

4. Sachs, "Classification of the Babylonian Astronomical Tablets," 282 n. 2.

5. Lis Brack-Bernsen, "Goal-Year Tablets: Lunar Data and Predictions," in *Ancient Astronomy and Celestial Divination*, ed. Noel Swerdlow (Cambridge, Massachusetts: MIT Press, 1999), 149–77 and Lis Brack-Bernsen and Hermann Hunger, "TU 11: A Collection of Rules for the Prediction of Lunar Phases and of Month Lengths," *SCIAMVS* 3 (2002): 3–90.

one Saros (or, 223 synodic months) earlier than the month in question, and the other measured one Saros and six months (that is, 229 synodic months) prior to the given month. At this point we shall simply indicate the procedure and refer to earlier publications for further details.[6]

The cuneiform texts give the procedure in words to the effect: in order to find ME in the new year, go eighteen years (that is, one Saros) back, take one third of the sum ME+GE_6 and add it to ME from the old year. We prefer to give the procedures in the form of equations. The one for finding ME is given in equation (1.4) below:

$$(\mathrm{NA_N})_{new} = (\mathrm{NA_N})_{old} - 1/3\,(\text{ŠÚ} + \mathrm{NA})_{old-6months}, \tag{1.1}$$

$$\text{ŠÚ}_{new} = \text{ŠÚ}_{old} + 1/3\,(\text{ŠÚ} + \mathrm{NA})_{old}, \tag{1.2}$$

$$\mathrm{NA}_{new} = \mathrm{NA}_{old} - 1/3\,(\text{ŠÚ} + \mathrm{NA})_{old}, \tag{1.3}$$

$$\mathrm{ME}_{new} = \mathrm{ME}_{old} + 1/3\,(\mathrm{ME} + \mathrm{GE_6})_{old}, \tag{1.4}$$

$$(\mathrm{GE_6})_{new} = \mathrm{ME}_{old} - 1/3\,(\mathrm{ME} + \mathrm{GE_6})_{old}. \tag{1.5}$$

Note that the new and old months are exactly 223 synodic months, *i.e.*, one Saros apart. For finding the new $\mathrm{NA_N}$, the value of $\mathrm{NA_N}$ from the lunation one Saros earlier was used in connection with the sum ŠÚ+NA measured one Saros and six months earlier.

TU 11 has traces of these five formulæ, but nothing on KUR. However, corresponding to equation (1.1), the reconstructed formula for calculating KUR must be

$$\mathrm{KUR}_{new} = \mathrm{KUR}_{old} + 1/3\,(\mathrm{ME} + \mathrm{GE_6})_{old-6months}. \tag{1.6}$$

Here one must read $(\mathrm{ME{+}GE_6})_{old-6months}$ as the sum ME+GE_6 measured eighteen years plus six months earlier than the new month in question. Until now this reconstruction has not been supported by textual evidence. Luckily, BM 37110 seems to be concerned with finding KUR by means of the Goal-Year Method, so now we have the textual confirmation for the procedure postulated in equation (1.6).

The Textual Proof

Of BM 37110 only one side is preserved—the beginning and the end are lost as well as the beginning and end of each line. Still, what is left clearly refers to the Goal-Year method. It mentions eighteen years, a new year, an old year, the last visibility (i.e., KUR) and tells us to go six

6. For a more thorough explanation, astronomical comments and textual evidence, see Brack-Bernsen, "Goal-Year Tablets." See also Brack-Bernsen and Hunger, "TU 11."

months back (from month I to month VII). Therefore we surmise that lines 3’ to 5’ of BM 37110 are concerned with rules for finding KUR:

3’ [GABA-RI 18 *ana* DÙ-*ka* TA BAR *šá* 18] 6 ITU TA BAR GUR-*ma* [20 ME *u*] GE$_6$ *šá* DU$_6$ [. . .]
4’ [. . . *šá* BAR *šá*] 18 X TAB-*ma ki-i* $\frac{2}{3}$ DANNA *i tab lu ka* [. . .]
5’ [. . . ME *u* G]E$_6$ *bal-ṭu šá* DU$_6$ TA UD.NÁ.A *šá* BAR ZI-*ma* [. . .]

3’ [In order for you to calculate the equivalent for 18 (years): from month I of the 18(th year preceding)] you return 6 months from month I, and [one-third of] ME+GE$_6$ of month VII [. . .].
4’ [. . . of month I of] the 18(th year preceding) you add, and if . . . two-thirds of a beru [. . .].
5’ [. . .] you subtract the complete ME+GE of month VII from KUR of month I [. . .].

Now, lines 3’, 4’, and 5’ are so similar to and parallel to TU 11, section 16, that we can identify the procedure and add the missing text. Section 16 gives the rule for finding NA_N and for correcting the result if the calculated NA_N happens to become smaller than 10 *uš*, so that the moon will not be visible. In this case, NA_N will be visible on the next day, and its value will become larger by the whole ŠÚ+NA, which is the daily retardation of the setting moon. The remnants on BM 37110 can be identified as the Goal-Year procedure for finding KUR and for the correction necessary if the calculated KUR happens to be larger than $\frac{2}{3}$ DANNA (that is, 20 *uš*). In such a case, the old moon would probably be visible one day later than first assumed. Consequently, its calculated value shall be reduced by $(\text{ME}+\text{GE}_6)_{old-6month}$, which is the daily retardation of the rising moon.

The procedure for finding NA_N, together with the corrected rule for the case when the new NA_N happens to become too small, is given in equation (1.1) and (1.7).

Section 16 of TU 11 gives the Goal-Year procedure for lunations two Saroi apart, which is equivalent to equation (1.1) used twice. The text BM 37110 mentions 18. Clearly, it is concerned with lunations one Saros apart. Therefore, below we give the formula and correction for finding NA_N after one Saros.

$$(\text{NA}_\text{N})_{new} = (\text{NA}_\text{N})_{old} - 1/3\,(\text{ŠÚ} + \text{NA})_{old-6months}. \tag{1.1}$$

If $\text{NA}_\text{N} < 10$ *uš*, a correction may be made by adding the whole ŠÚ+NA:

$$(\text{NA}_\text{N})_{new_C} = (\text{NA}_\text{N})_{old} + 2/3\,(\text{ŠÚ} + \text{NA})_{old-6months}. \tag{1.7}$$

Similarly, the formula for the corrected KUR can be derived from equation (1.6):

$$\text{KUR}_{new} = \text{KUR}_{old} + 1/3\,(\text{ME} + \text{GE}_6)_{old-6months}. \tag{1.6}$$

If $\text{KUR}_{new} > 20$ *uš*, a correction may be made by subtracting the whole $\text{ME}+\text{GE}_6$:

$$\text{KUR}_{new_C} = \text{KUR}_{old} - 2/3\,(\text{ME} + \text{GE}_6)_{old-6months}. \tag{1.8}$$

We are convinced that BM 37110 is concerned with these rules. As evidence, we reproduce below TU 11, obv. 36 and 37. In these lines, the rule for finding NA_N from its value established two Saroi earlier is given together with corrections for the case of NA_N becoming too small.

36 GABA-RI 36 *ana* DÙ-*ka* TA BAR *šá* 36 6 ITU BAR GUR-*ma* 40 *šá* ŠÚ *u* NA *šá* DU_6 GIŠ-*ma* TA NA *šá* UD-1

37 *šá* BAR *šá* 36 ZI-*ma* BE-*ma al-la* 10 UŠ LAL ŠÚ *u* NA *bal-ṭu-ut* *ana* UGU DAḪ . . .

Lines 36 and 37 of TU 11 are quite similar to lines 3' through 5' of BM 37110, which we see as the rule for finding KUR from its value established for the lunation one Saros earlier together with corrections to be applied in case the old moon could be seen one day later.

It is obvious that the two sections are parallel. Both texts give advice for times when two elements of the Lunar Six—NA_N and KUR—eventually could (and hence should) be measured a day later than the standard procedure. There is, however, an asymmetry with the observable NA_N and KUR. If the new NA_N becomes so small that it is questionable whether or not the new crescent will be visible on the expected evening, then, in a clear sky, it will always be observable the next evening. Likewise, KUR—as found by equation (1.6)— can become so large that the old moon might still be visible the next morning, but one cannot be sure. A large KUR does not guarantee that the old moon really will be visible one day longer than expected. It should be tested. The text says if KUR becomes larger than 20 *uš*, subtract ME+GE. But, ME+GE varies between roughly 6 *uš* and about 18 *uš*, so that $\text{KUR}_{new_C} = \text{KUR}_{new} - (\text{ME}+\text{GE}_6)$ might become too small (smaller than 8 to 10 *uš*) for the old moon to be visible. The text should give a limit for the new and corrected KUR.[7]

7. We thank John Britton for fruitful discussions. He proposed that the text might have had rules for checking the size of the new KUR and through that for controlling the visibility of the KUR_{new_C}.

References

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