Gerd Graßhoff and Erich Wenger

The Coordinate System of Astronomical Observations in the Babylonian Diaries

Summary

A large number of the astronomical observations in the Babylonian diaries are occurrences of close conjunctions of moving objects, such as the Moon or planets with bright stars, in the vicinity of the ecliptic. In 1995, Graßhoff proposed the hypothesis that the observations fit best when one assumes that the Babylonians used an ecliptical coordinate system. In the following we present a test that excludes an equatorial coordinate system as an alternative system of measurement.

Keywords: Babylonian astronomy; observations; coordinate system; astronomical diaries; lunar observations; C. Ptolemy.

Ein Großteil der astronomischen Beobachtungen in den Babylonischen Tagebüchern handelt von Konjunktionsereignissen sich bewegender Objekte, wie dem Mond oder Planeten mit hellen Sternen in der Nähe der Ekliptik. 1995 argumentierte Graßhoff, dass die Beobachtungen am meisten Sinn ergäben, wenn man davon ausginge, dass die Babylonier ein ekliptikales Koordinatensystem nutzten. Im Folgenden stellen wir einen Test vor, der ein äquatoriales Koordinatensystem als alternatives Messsystem ausschließt.

Keywords: Babylonische Astronomie; Beobachtungen; Koordinatensystem; astronomische Tagebücher; Mondbeobachtungen; K. Ptolemaios.

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1 Introduction

In 1987 Otto Neugebauer suggested that Gerd Graßhoff reanalyze what seemed to be observational reports in the Babylonian astronomical diaries, which were being prepared for publication by Hermann Hunger on the basis of the notes of the late Abraham Sachs. Hunger kindly gave Graßhoff access to his text files so that he could process the astronomical data. Thus, Graßhoff undertook a comparative analysis of the calculated positions of the Moon of the first two volumes of the *Astronomical Diaries* using the just published algorithms of Chapront-Touzé[1]. Until then, no one had carried out a systematic interpretation of the observational reports, which had fueled much debate between Neugebauer and Noel Swerdlow at Princeton, and which had led them to question whether the *Astronomical Diaries* had anything in common with the ACT. During one particular summer of intense discussion on the difficulties of interpreting the reports, they had even argued about whether the Babylonian observers had used any modern astronomical coordinate system at all. In 1990 the early results showed that the observations of planetary configurations had been recorded using the ecliptical coordinate system. Swerdlow promptly took up the challenge and investigated the implications for Babylonian planetary theory.[2] The results concerning the Babylonian coordinate system were presented at a Dibner Institute workshop at the MIT in Boston in 1995. As statistical tests could not distinguish clearly between ecliptical and equatorial coordinates, the late John Britton suggested that future researchers look for properties in the data that would yield an *experimentum crucis* between both coordinate systems. This paper is a response to his suggestion.

The three volumes of late Babylonian texts, edited by Abraham Sachs and Hermann Hunger, and published by 1996,[3] contain the observations of more than 5 000 planetary and lunar configurations. Observations of this type record close approximations of the Moon or planets with bright stars in the vicinity of the ecliptic. According to Graßhoff, the general form of the observed configurations can be tabulated as shown in Tab. 1.

A number of the observational reports mention more than one topographical relationship and their quantity. These expressions have been translated as 'low to the south,' 'high to the north,' 'back to the west,' and 'passed to the east,' followed by another quantitative value. A schematic form of these expressions is:

at t: O_1 stands ['in front of' / 'behind'] O_2 with D, low to the south with N.

'Low to the south' and 'high to the north' measures ecliptical differences. The first object stands in the north if its difference of latitudes with the second object is positive.

1 Chapront-Touzé and Chapront 1991.

2 Swerdlow 1998.

3 Sachs and Hunger 1988–1996.

	standard	***back to the west***	***passed to the east***	***balanced***	**further specification**
	ecliptical difference of latitude, $\beta_1 > \beta_2$, $D_1 = \beta_1 - \beta_2$				
above	small difference of longitude	difference of longitude $\lambda_1 < \lambda_2$, $D_2 = \lambda_2 - \lambda_1$	difference of longitude $\lambda_1 > \lambda_2$, $D_2 = \lambda_1 - \lambda_2$	very small difference of longitude	—
	ecliptical difference of latitude, $\beta_1 < \beta_2$, $D_1 = \beta_2 - \beta_1$				
below	small difference of longitude	difference of longitude $\lambda_1 < \lambda_2$, $D_2 = \lambda_2 - \lambda_1$	difference of longitude $\lambda_1 > \lambda_2$, $D_2 = \lambda_1 - \lambda_2$	very small difference of longitude	—

	standard	***high to the north***	***low to the south***	***balanced***	**further specification**
	ecliptical difference of longitude, $\lambda_1 < \lambda_2$, $D_1 = \lambda_2 - \lambda_1$				
in front of	undetermined difference of latitude	difference of latitude $\beta_1 > \beta_2$, $D_2 = \beta_1 - \beta_2$	difference of latitude $\beta_1 < \beta_2$ $D_2 = \beta_2 - \beta_1$	very small difference of longitude	occasionally with planets: *to the west*
	ecliptical difference of longitude, $\lambda_1 > \lambda_2$, $D_1 = \lambda_1 - \lambda_2$				
behind	undetermined difference of latitude	difference of latitude $\beta_1 > \beta_2$, $D_2 = \beta_1 - \beta_2$	difference of latitude $\beta_1 < \beta_2$, $D_2 = \beta_2 - \beta_1$	very small difference of latitude	occasionally with planets: *to the east*

Tab. 1 Summary of the meaning of the relational expressions (rows) and the additional remarks (columns) used; for configurations between celestial bodies O_1 und O_2 with ecliptical coordinates λ_1, β_1 and λ_2, β_2. The measurement is denoted as D_1, accompanied by D_2 in the case of dual coordinates. Cf. Graßhoff 1999.

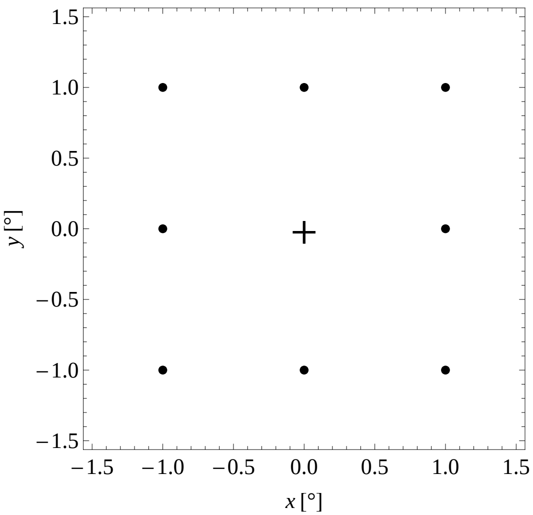


Fig. 1 Two hypothetical objects displayed in a distance relationship using an abstract coordinate system.

2 Babylonian astronomical observations of planetary and lunar configurations

2.1 Measuring coordinate differences

Let us begin with looking at an abstract generalization of the observation of a configuration of two objects with dual coordinates in a measuring plane (x, y) as shown in Fig. 1. The position of the second (slower or fixed) object is marked in the center of the observation window by a cross. The positions of eight other objects are marked by bullet points, with their respective coordinate differences. In standard Babylonian formulation they would be mentioned as the first objects. Their position follows a square of a length of one degree around the cross in the center. The standard form of a configuration statement is:

> 'At date D, the second object (e.g. the Moon) is situated at distance A below object 2 (e.g. the star *Beta Tauri*) and at distance B towards the east.'

As in the aforementioned example, we here have the simulation of a coordinate difference (A, B) of two hypothetical objects defined by their distance. The coordinates themselves refer to a coordinate system, and the coordinate differences are indicated on the measuring plane (x, y). It is our goal to identify which coordinate system the Babylonians used.

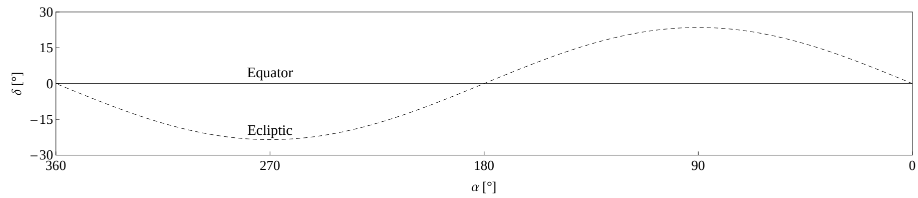


Fig. 2 The Sun moving along the ecliptic.

2.2 Comparison of observations using recalculated positions

The procedure for identifying the coordinate system is based on a method which uses the systematic errors that occurred in the data when the coordinate system assumed to have been used by the Babylonians to take their measurements is, in fact, the wrong one. As the characteristic errors for an assumed measurement procedure usually appear as systematic errors in the obtained data differences, we, therefore, analyzed the observations by comparing them with modern recalculations. The coordinate differences between the observed values and the recalculated values can give us clues about the correctness of the assumed coordinate system, as such differences appear much the same in different coordinate systems, although they are not uniform for different regions of the sky.

If the Babylonian observations had been recorded as angular differences in a coordinate system that differs from the coordinate system we used to recalculate the differences, then characteristic errors, which vary in size and direction across the sky, would occur. It is, therefore, not enough to take the mean deviations of the calculated positions of the stars for all the observations made (irrespective of their position in the sky) or to examine statistically their dispersion. Because of the variations in coordinate differences, one cannot simply use standard fits to identify the underlying coordinate system.

2.3 Systematic errors

The annual path of the Sun follows the ecliptic, and is plotted as a line of dots in Fig. 2. The ecliptic crosses the celestial equator at the spring (0°) or autumn equinoxes (180°). All our calculations refer to the equinoctial points and solstices at the time of observation. When we could compare the coordinate differences originally recorded using an equatorial coordinate system with the recalculated positions within an ecliptical reference system, we introduced a specific systematic error.

First, we show the effect with simulated data. Let us superimpose the zero points of the equatorial and ecliptical celestial coordinate systems in Fig. 3: the left column shows the position of stars plotted using the equatorial coordinate system. It should be noted that the values increase from right to left.

Now, if the observations had been made in one of the coordinate systems, and the positions of the two objects had been calculated in the other coordinate system, then typical systematic errors should have occurred:

- The coordinate systems would have rotated against each other at the spring and autumn equinoxes. The difference vectors would have rotated as well.
- The coordinate systems would have lain parallel at the summer and winter solstices. And there would be no differences in the measurements of angular distances at the solstices.

At the equinoxes the ecliptic is inclined maximally towards the equator; the corresponding directions of the angular distances between the two celestial objects incline by the same degree.

The aim of our procedure is to determine whether such a systematic turn can be detected in the reconstructed data or not. If the angular distances recorded in the observational reports are compared with the recalculated differences using the wrongly assumed coordinate system, a characteristic rotation would show up in the data. Therefore, the method should clearly falsify the incorrect assumptions made about the assumed measurement procedures. If the right coordinate system was chosen for the recalculations, then the systematic rotational error should not appear. In order to simulate the effects of the presumed coordinate systems, we will now take a look at the positions of pairs of celestial bodies in their respective regions of the sky.

2.3.1 True equatorial system compared with equatorial data

First, we test the assumption that the observations were based on the equatorial system by transferring the abstract observations from Fig. 3 to the equatorial coordinate system. This is done four times at the aforementioned key positions. We then distribute eight objects in the square around object two in the middle column, each with an angular difference of 1° in one of the coordinates (left of Fig. 3). The corner coordinates of the respective points are situated at a distance of 1° up or down and 1° to the right or left from the reference object in the middle of the square. When we calculated the positions of all the celestial objects using the equatorial coordinate system, we got a figure identical to the one at the left-side diagram of Fig. 3. In general, rotations would only occur if we used the wrong coordinate system to recalculate the positions.

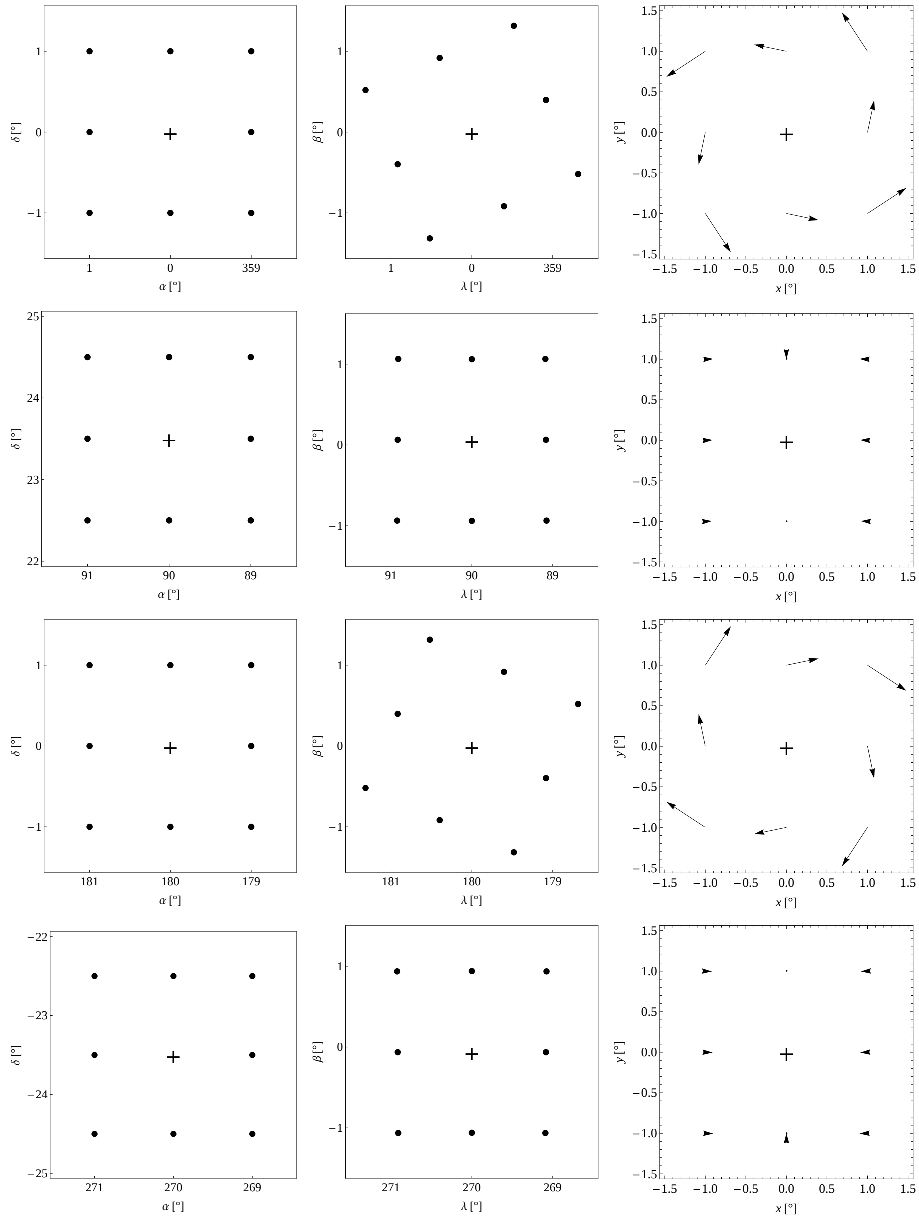


Fig. 3 Left column: coordinate differences on all four cardinal points of an equatorial system. Middle column: coordinate differences on all four cardinal points of an ecliptical system. Right column: differences of the distances. Rows from top to bottom: spring equinox (SE), summer solstice (SS), autumn equinox (AE), winter solstice (WS).

2.3.2 *True equatorial system compared with ecliptical data*

If we now calculate the same object using the corresponding ecliptical coordinate system, Fig. 3 shows that no discernible deviations can be noticed in the solstices. However, there is a noticeable rotation at the equinoxes, which falsifies the hypothesis that the original observations were made using an ecliptical coordinate system.

2.3.3 *True ecliptical system compared with ecliptical data*

We will now assume that the Babylonians made their measurements using the ecliptical system, and we will then calculate the deviations between both the ecliptical and the equatorial recalculations. If the coordinate system used for making the observations and the recalculations are the same, then no noticeable rotation should appear at the equinoxes, and no rotation at the solstices.

If we look for the vernal point at the top row diagram, the shaft ends of the arrows stand where the celestial bodies are located in accordance with the equatorial coordinate system of Fig. 3, whereas the arrowheads indicate the shifted position of the object's coordinates according to the recalculated ecliptical coordinate system.

As the Babylonian observations recorded the angular distances between two objects, the systematic deviations of the angular distances systematically superimposed the measured values: there are hardly any differences at the solstices, but there are rotations at the vernal and autumnal points.

It is important to note that we depict the differences between the calculated and observed positions using the measuring system (x, y) and not using a celestial coordinate system. By way of example: the greater the distance between object 1 and object 2 in the top row illustration, the greater the deviation will be. At the solstices, the axes of the two coordinate systems are parallel to each other and so there should be no deviations. The systematic rotation thus only appears relatively in the measuring system, not absolutely in the sky. Hence, it is only visible when comparing Babylonian observations with distances, recalculated using different test coordinate systems.

2.3.4 *The ecliptical coordinate system*

The systematic errors will be reversed when the assumed coordinate system is ecliptical, and the equatorial system is used for calculating the positions.

Again, the actual differences of the eight objects around the reference object in the middle are only shifted by 1° in a coordinate and thus, in sum, all these deviations result in a square distribution around the second object.

If we superimpose the equatorial coordinate system over the actual ecliptical coordinate system, the typical rotations of the differences occur at the equinoxes – only in reverse. The values of the angular distances rotate clockwise at the vernal point and counterclockwise at the autumnal point. This is a general definition of the test method. Thus, the test method is defined in general terms.

2.4 Test procedure

Because of these complementary systematic errors, we can set up a test procedure for determining which coordinate system was used.

1. Based on the observed angular distances, we calculate the positions of object 1, in both the equatorial and in the ecliptical systems. We compare these positions using state-of-the-art coordinate calculations of the objects. We then plot the deviations in the measuring system (x, y).

2. If the Babylonians did their measurements using the equatorial system, but we evaluated their findings using the ecliptical system, we should be able to observe a faulty counterclockwise rotation at the vernal point and a clockwise rotation at the autumnal point. No rotations should appear at the solstices.

3. If the Babylonians made their measurements using the ecliptical system, but we evaluated their findings using the equatorial system, then we should observe a faulty clockwise rotation at the spring point and a counterclockwise rotation at the autumn point. No rotations should appear at the solstices.

4. If we made our comparisions using the same coordinate system as the Babylonians, there should be no rotations at all.

We thus arrive at a sensible testing procedure (Tab. 2).

	ecliptically calculated	**equatorially calculated**
ecliptical Babylonian	no rotations	SE: clockwise|AE: countercl.
equatorial Babylonian	SE: countercl.|AE: clockwise	no rotations

Tab. 2 Decision criteria for best-fitting coordinate system.

We thus obtain two different tests that enable us to ascertain which coordinate system the Babylonians used. Based on the observed angular distances of the two recorded celestial objects, we calculate their positions twice: once using the ecliptical system, once using the equatorial system. The distribution of the findings depicted in Tab. 2 reveals why one should apply the systems that the Babylonians used.

2.5 With stochastic errors

Before we analyze the real data, let us look at the effect of random errors in the observations, which occurred when the Babylonian took their measurements.

2.5.1 Equatorial coordinate system for observation

The observations of the Babylonian astronomers show small, random errors, as is the case for all empirically measured values. These so-called stochastic errors randomly influence the measured positions of the two objects. The question then arises as to whether these statistical errors overlap the systematic errors in such a way that we can no longer discern the rotations.

In Fig. 4, the eight positioned objects show a random error of deviating from 1° in x and y. The first example is based on the equatorial coordinate system and the random errors concerning the equator are superimposed on both coordinate systems.

If we now calculate the positions of the objects using the ecliptical coordinate system, even if the observations were made equatorially, then the systematic error of the aforementioned discussion overlaps with the stochastic error of the individual observation. As a result, we can discern the meanwhile well-known rotation of the deviations of the angular distances of both objects.

2.5.2 Ecliptical coordinate system for observation

In the case of the observation of the positions in the ecliptical coordinate system and the subsequent calculation of the position in the equatorial coordinate system, we can observe a similar superimposition with stochastic errors. The only difference is that in this case the systematic errors rotate in the reverse direction in the solstices. In the solstices only random errors are visible.

If, in this case, no rotation appears, but we can could observe stochastic errors in such a dimension that a rotation of the coordinates is visible, then the calculated ecliptical coordinates in fact match the observed data.

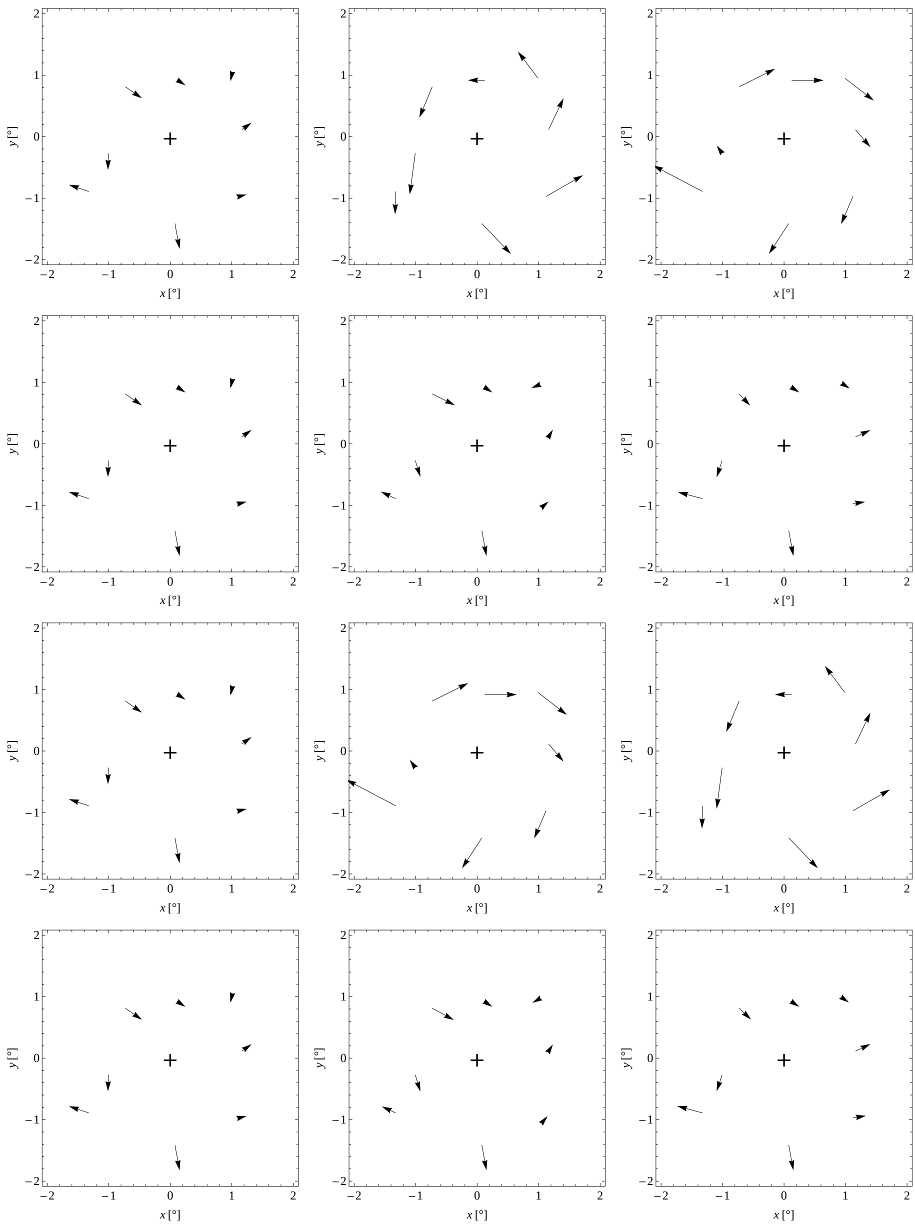


Fig. 4 Superimposed stochastic errors plus systematic errors. Left column: no systematic errors. Middle column: systematic from recalculated ecliptical instead of equatorial system. Right column: equatorial instead of ecliptical coordinate systems. Rows from top to bottom: spring equinox (SE), summer solstice (SS), autumn equinox (AE), winter solstice (WS).

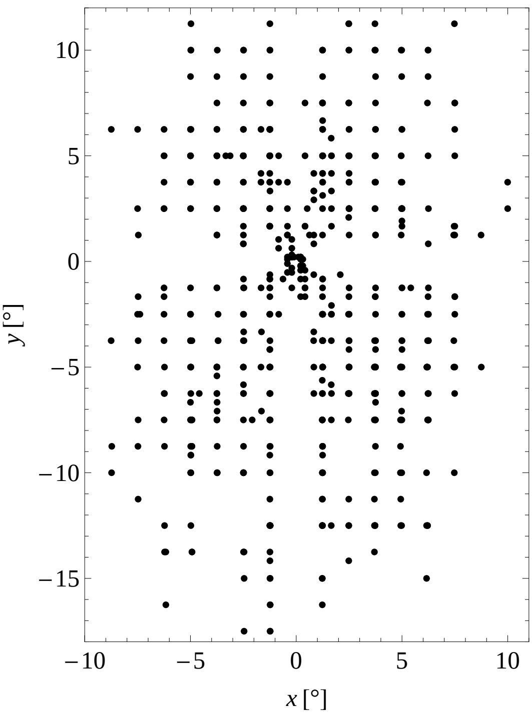


Fig. 5 Double coordinate observations of coordinate differences.

2.6 Analytical findings

In the following, we investigate the measurements of configurations with double coordinates. Outliers with a deviation of more than 5° have been excluded. The number of observations comprises 595 measurements. If we transfer the observed angular distances to the second object, which is situated at the origin of the measuring system, we get the distribution shown in Fig. 5. It can be seen clearly that the Babylonians measured the northern and southern distances in latitude for greater distances than in the case of the longitudes.

This is in fact a consequence of the moment when the measurement was made: The moment is recorded when the first object passed the second object above the horizon, with as little distance as possible – a movement which can be observed. As the solar system objects, including the Moon, move along the ecliptic, the smallest distance to the second object is determined by two aspects for both coordinates: the minimal latitude is given by the ecliptical difference in latitude of both objects and varies depending on the ecliptical latitude of the first object. The minimal length is determined by the

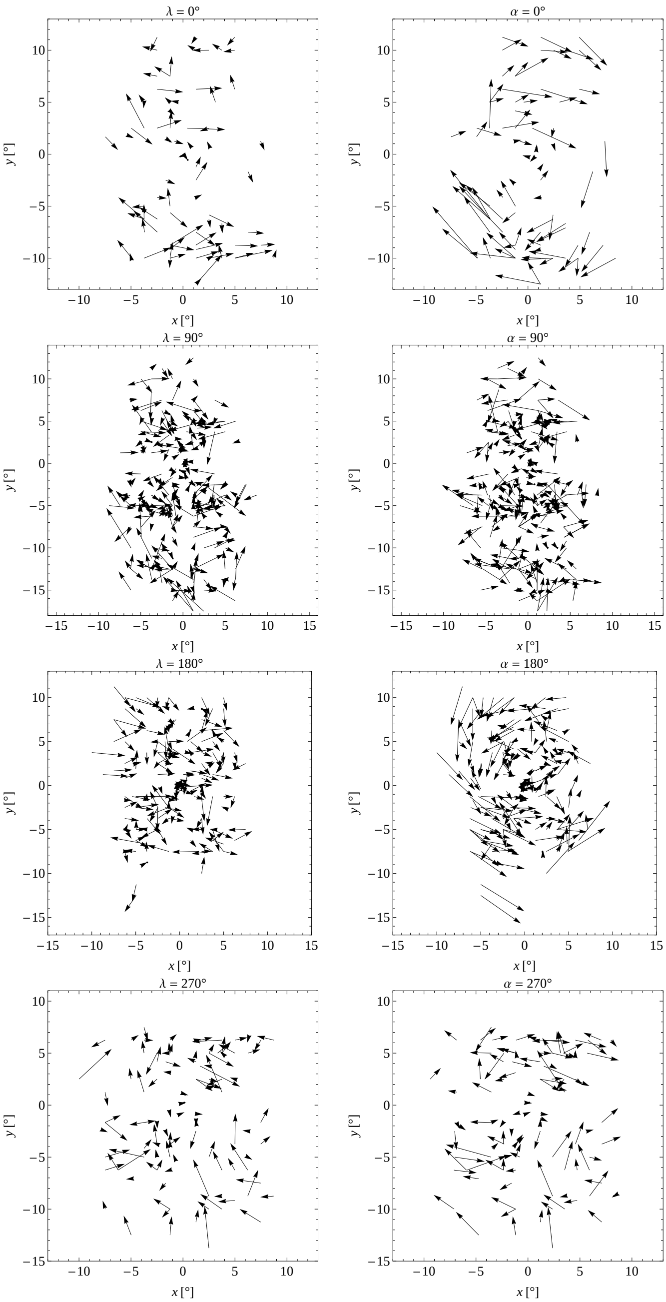


Fig. 6 Differences of distance vectors using ecliptical coordinates (left) and equatorial coordinates (right) for all cardinal points. Rows from top to bottom: spring equinox (SE), summer solstice (SS), autumn equinox (AE), winter solstice (WS).

observation window, which was just big enough to make the measurement of the passage possible. It is due to these aspects that both measuring coordinates show a different dispersion in the measurement area. However, this does not mean that both coordinates comprise differently sized measurement errors. The measuring accuracy could still be similar for both coordinates.

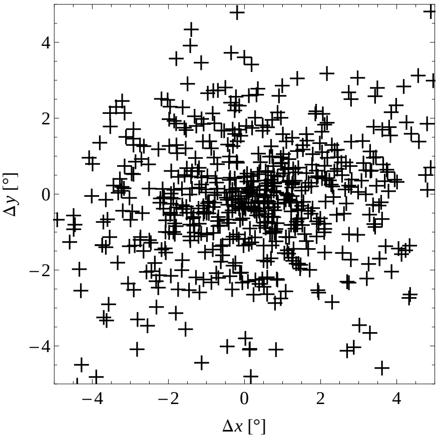
We have now calculated the positions of the celestial bodies in ecliptical and equatorial coordinates in order to analyze the characteristics of the data. We have calculated the coordinate differences for our measurement system (x, y), which can be deducted from these data.

Using four rectangles measuring $90^\circ \times 180^\circ$, we have chosen observations for which the second object is situated within this field. Fig. 6 comprises the findings: the left-hand column shows the calculated ecliptical coordinate differences starting from the vernal point (in the uppermost row) to the winter solstice in the fourth row. The right column shows the coordinate differences for the equatorial calculation for the same regions in the sky. Let us first look at the right column. In the uppermost row, we calculate the coordinates for the vernal point, using equatorial coordinates. We receive a characteristic rotation in a clockwise sense. If we calculate the errors in the ecliptical coordinate system in the first column, no rotations appear. The findings for the autumnal point show the same results. For the calculation in the equatorial coordinate system, the errors appear as counterclockwise rotations. The errors rotate counterclockwise as a result of a systematic error due to the fact that the equatorial coordinate system has erroneously been applied. As can be seen, the calculation of the coordinate difference for the ecliptical calculation shows no rotations. These findings unambiguously establish that the Babylonians used the ecliptical coordinate system to record their data. The reported quantities of the configurations of two celestial objects measure coordinate differences.

3 Further corroborating findings

3.1 Magnitude of error vectors

The orientation of the systematic error vectors is the crucial argument for deciding which coordinate system was used by the Babylonians. Nevertheless, the magnitude of the total error vectors (i.e. systematical plus stochastic errors) should support this argument. In Fig. 7 we compiled the errors, once assuming the ecliptical and once assuming the equatorial system.



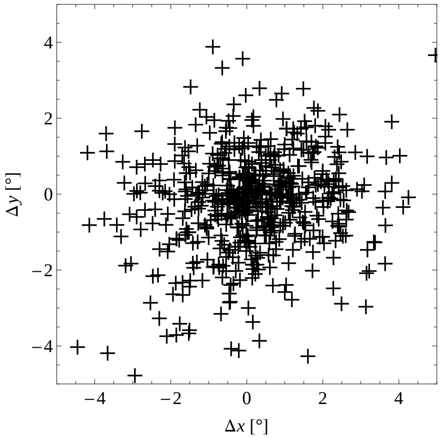


Fig. 7 Distribution of positional errors: if (a) the recalculated positions are given in equatorial coordinates; or (b) in ecliptical coordinates. Note that the distribution is denser when ecliptical coordinates are used, which is equivalent to a better fit of the recalculated and the documented data.

The corresponding RMS errors are found in Tab. 3 and were calculated by ($n = 595$):

$$\text{RMS error} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_{i,\text{observed}} - x_{i,\text{computed}}\right)^2}$$

	equatorial	ecliptical	error decrease
x-direction	2.05°	1.51°	–26.4%
y-direction	1.57°	1.27°	–19.1%

Tab. 3 RMS errors in x- and y-direction, assuming the ecliptical and equatorial coordinate system, respectively.

3.2 Special cases

In Fig. 8 we display a Babylonian observation that reads: 'in the last part of the night the moon is 5° above mars and 0.5° passed to the east' (observation no. 5975). Calculated in the ecliptical system, the Moon (dots) is always East from Mars (center cross) from the first sight possible of the Moon (Moonrise) until the last sight possible (Sunrise). Calculated in the equatorial system, however, the Moon is never East but always West of Mars

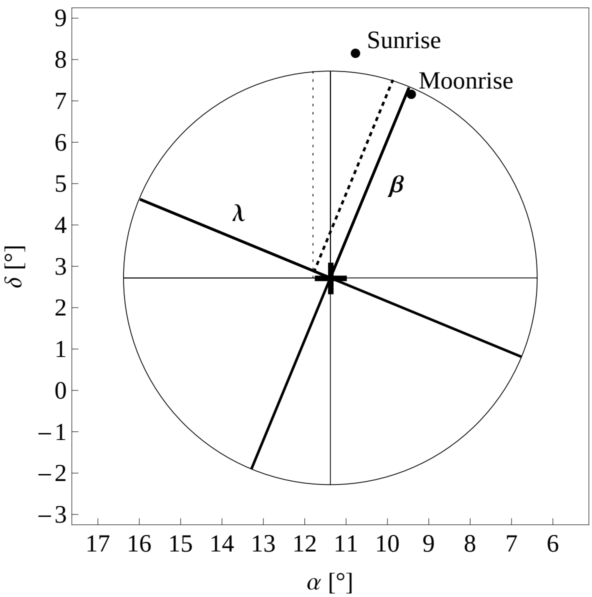


Fig. 8 Observation No. 5975. Cases of different relational configurations depending on the compared coordinate system.

throughout the possible time of visibility. Thus, if the Babylonian used the equatorial system, they must have confused the directions East and West.

Now, there are 30 observations, which were coincidentally made in one of the four quadrants built by the equatorial and the ecliptical coordinate axes (see Fig. 8). 25 of these observations can be explained in both systems, due to the uncertainty of the observation time, whereas five observations (like the one mentioned) cannot. For each and every of these five observations, the ecliptical system fits, whereas the equatorial doesn't. So, if we assume the equatorial system as correct, we would have to accept that the Babylonians confused the directions East-West and North-South exclusively for these five observations. If we assume the ecliptical system as correct, all indications of directions (including the 25 others) are correct.

3.3 Other ancient witnesses

Babylonian astronomy strongly influenced Ptolemaic astronomy, particularly through the work of Hipparchus, in whose *Commentary on the Phenomena of Aratus and Eudoxus* we find extensive usage of Babylonian terminology.[4] Ptolemy referred to two observations

4 Cf. Neugebauer 1975, 279–281, 304, 544, and 591–593.

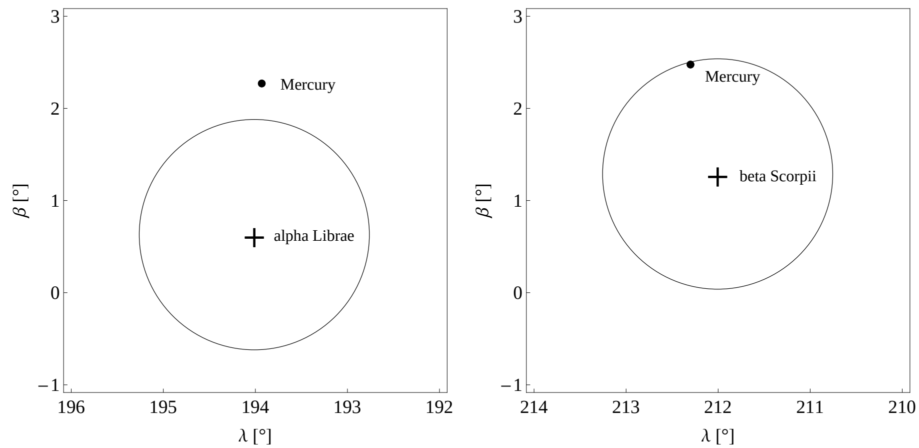


Fig. 9 Mercury's approximate position relative to the stars, according to Ptolemy's description.

of Mercury that seem to be of Babylonian origin,[5] and used them to derive his planetary model. He quoted the two observations without fully converting them to the Greek metrological system:

> In the 75th year in the Chaldean calendar, Dios 14, at dawn, [Mercury] was half a cubit [ca. 1°] above [the star on] the southern scale [of Libra]. Thus at that time it was in ♎ $14\frac{1}{6}^{\circ}$, according to our coordinates. […]
>
> In the 67th year in the Chaldean calendar, Apellaios 5, at dawn, [Mercury] was a half a cubit [ca. 1°] above the northern [star in the] forehead of Scorpius (β). Thus at that time it was in ♏ $2\frac{1}{3}^{\circ}$, according to our coordinates.[6]

See Fig. 9 for the computation of Mercury's position relative to the stars for the aforementioned dates.

Ptolemy paraphrased both observations in the form of topographical relationships 'object 1 above object 2 by X cubits (Babylonian: kùš)', which is clear proof of their Babylonian origin. Even more interesting are the details of his evaluation. The quantities are measurements of the differences in latitude between Mercury and the particular star. Ptolemy, however, used this observation to determine planetary longitude. How did he arrive there?

5 Cf. Neugebauer 1975, 159.
6 Ptolemy, *Almagest* Book IX, ch. 7, cited from Toomer 1984, 452. The omission […] and the insertion in round brackets ('β') are made by the authors, all other bracketed insertions were added by Toomer.

If he reduced the stellar longitudes for the epoch of the observations, according to his theory he had just to subtract the value for the precession: $3^\circ\ 50'$ for 373 years in the case of the first observation and 4° for 381 years for the second observation.[7] In the star catalog of the *Almagest*, β Scorpii has a longitude of ♏ $6^\circ\ 20'$ and α Librae a longitude of ♎ 18°. In the second case, the resulting longitude would be a little too large. It is plausible that Ptolemy did not reduce the longitudes from the star catalog, but used Hipparchus' value or, alternatively, that of the Babylonian astronomers, and then added the precession constant to these values.

Independent of the exact derivation of the longitude, it is remarkable that Ptolemy assumed that Mercury and the stars have *the same longitude*. He seemed to find the measured coordinate of half a kùš unimportant to the calculation, which demonstrates that he interpreted the Babylonian report in two ways:

1. The measured topographical relationship is a coordinate value, e.g. either longitude or latitude.

2. Since he identified the other coordinate with the longitude, the topographical relationships need to be understood in the framework of the ecliptical coordinate system.

Ptolemy took these excerpts from Hipparchus, who had extensive access to Babylonian ideas.[8] Without a doubt Ptolemy fully understood the meaning of the Babylonian observation reports.

4 Conclusion

At the time of the first publication of the Babylonian diaries by Hermann Hunger, it was completely unclear whether the observations of the moon passages along the stars or planets were at all measured, and if they were, which astronomical reference system had been applied. In 1995, the research results on Babylonian astronomical diaries were presented at the Dibner Institute in Boston. According to these results, the ecliptical system has been 'diagnosed' to be the system that matches the documented data best.[9]

7 Note that Ptolemy uses a precession constant of one degree per one hundred years, which is much too small.

8 I have purposefully avoided referring to 'sources', although it is highly probable that Hipparchus had comprehensive access to either original or transcribed Babylonian sources, considering the wealth of Babylonian concepts that he utilized. Cf. Toomer 1984.

9 Alexander Jones extended the testing of the hypothesis to the case of configuration observations of planets in Jones 2004.

A more elaborate argument has been developed in the article presented here. This argument tries to examine to what extent the assumption of a specific coordinate system would generate characteristic errors in the statistical data, and whether these errors would rule out the application of such a coordinate system. This elimination procedure is very specific and statistically significant, and surpasses the levels of significance of usually applied evaluation criteria. The comparison of the two main hypotheses for the reconstruction of the Babylonian coordinate system presented here show clear differences with regard to their exclusion criteria. The equatorial coordinate system creates specific rotation effects in the reconstructed quantitative data, which change their rotation direction according to the celestial quadrant. The rotational quadrants can be identified in the database. Thus, the configuration data of the Babylonian diaries was not recorded in an equatorial system, as the alternative ecliptical system does not show these rotation effects.

This evidence, together with the earlier research results, strongly supports the hypothesis that the Babylonian astronomers either directly observed or calculated passages in the ecliptical coordinate system and systematically noted down their observations on a day-to-day basis.

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