

Ph.D. THESIS:

**The Definition of the Babylonian Zodiac
and the Influence of Babylonian Astronomy
on the Subsequent Defining of the Zodiac**

Robert Powell

SUMMARY

This thesis on the definition and transmission of the zodiac is concerned with the original specification of the zodiac, i.e. the first scientific definition of the zodiac.

According to this original definition the zodiac is defined by the two first magnitude stars Aldebaran and Antares in such a way that each is located exactly at the midpoint (15°) of their respective sign, Taurus and Scorpio. Thereby these two stars define the central axis of the zodiac, which was the primary zodiacal reference axis for all other stars. On the basis of observation and measurement in relation to this reference axis, the brighter stars near the ecliptic belonging to the twelve zodiacal constellations were assigned longitudes in the zodiac, for example the stars α and β Librae were assigned the longitudes 20° and 25° Libra. Thus the first astronomical coordinate system came into being, through which the positions of the stars and planets along the ecliptic could be determined between 0° and 30° within the twelve zodiacal signs.

This coordinate system of twelve zodiacal signs, i.e. twelve equal-length zodiacal constellations each 30° long, emerged in Babylonian astronomy during the fifth century B.C. and was transmitted from Babylon to Greece, Hellenistic Egypt, Rome, and India. It had a forerunner in the schematic solar calendar of MUL.APIN (seventh century B.C.), which comprised a division of the year into twelve solar months relating to the sun's movement in declination.¹ This solar calendar was possibly the forerunner of that of the Greek astronomer Euctemon (fifth century B.C.). Euctemon's solar calendar went through a metamorphosis – probably through Hipparchus (second century B.C.) – to become the tropical zodiac, one of the standard coordinate systems of astronomy.²

A list of 17 constellations, some of whose stars lie within the moon's path on or close to the ecliptic, is also given in MUL.APIN. This too, since all twelve zodiacal constellations are named in this list, was a forerunner of the zodiac.

Between the fifth and the third centuries B.C. a development occurred from the early MUL.APIN level of Babylonian astronomy to the highly developed mathematical astronomy of Systems A and B based on computations using the ecliptic coordinate system of the sidereal zodiac as defined above in relation to the stars.³ This new level of astronomy relied on the one hand on the ecliptic coordinate system of the Babylonian sidereal zodiac and on the other hand on the availability of records of astronomical observations collected over an extended period of time.

It is unknown through whom the innovation leading to the introduction of the zodiacal coordinate system into Babylonian astronomy took place. It was made possible by the observation of the heavens as a systematic program carried out over hundreds of years, and it is an astonishing fact of the history of science that this systematic observation of the night sky was executed by Babylonian astronomers over many centuries.

In the last analysis this thesis pays tribute to those early astronomers who kept records of their observations and were able on this basis to arrive at the innovation of the ecliptic coordinate system of the zodiac, which was central to the whole subsequent development of astronomy as a science.

The original contribution of this thesis to the history of astronomy is the uncovering of the *intrinsic definition* of the Babylonian sidereal zodiac. This definition is intrinsic, because it is nowhere explicitly stated in the available cuneiform sources. Nevertheless the placing of Aldebaran at 15° Taurus and Antares at 15° Scorpio is the foundation for the definition of the zodiac.

Observation of the starry heavens reveals that the twelve zodiacal constellations (with the exception of Libra) are distributed such that their centers lie approximately 30 degrees from one another, and in the case of the constellations of Taurus and Scorpio their centers are marked by the bright stars Aldebaran and Antares. That which I have called the *intrinsic definition* of the zodiac, comprising the central content of this thesis, probably derives from the simple observation of the distribution of the circle of the twelve zodiacal constellations (as a division into twelve 30° -sectors or signs) around the celestial sphere.

This original definition of the zodiac of the Babylonians in the fifth century B.C. was a significant event in the history of astronomy as it heralded the beginning of the development of mathematical astronomy. Babylonian mathematical astronomy reached a highpoint during the Seleucid era (third and second centuries B.C.). However, although the Greek astronomer Hipparchus adopted some Babylonian astronomical parameters, he effectively redefined the zodiac when, rather than utilizing the Babylonian sidereal zodiac, he used instead the tropical zodiac, if indeed he really did utilize the tropical zodiac.⁴ Although the sidereal zodiac was transmitted from Babylon to Greece, Hellenistic Egypt, Rome, and India, it was replaced in Greek astronomy by the tropical zodiac. Thus the tropical zodiac is the standard astronomical coordinate system used in the second century A.D. by Ptolemy in the *Almagest*.

In addition to exploring in detail the original definition of the zodiac, a second original contribution of this thesis is the uncovering of the line of descent from the schematic solar calendar of the Babylonians from MUL.APIN to the tropical zodiac of Greek astronomy (Hipparchus and Ptolemy) via the solar calendar of Euctemon. Essential to understanding this line of descent is the insight that the Babylonian solar calendar and Euctemon's solar calendar are both an expression of the sun's movement in declination.

The tropical zodiac, as a spatial projection of Euctemon's solar calendar, is thus actually based on the sun's movement in declination, which is intrinsically independent of the sun's motion in longitude through the sidereal zodiac. Thus midsummer always occurs when the sun attains its maximum declination. However, the midsummer sun for Meton and Euctemon (432 B.C.) was in the constellation of Cancer (Meton specified it to be at 8° Cancer whereas it was actually at 9° Cancer in the Babylonian sidereal zodiac at that time). At the present time, however, on account of precession the midsummer sun is located in the constellation of Gemini (currently at 5° Gemini in the Babylonian sidereal zodiac). From this it is readily apparent that the two coordinate systems – that of the Babylonians (the sidereal zodiac) and the one favored in Greek astronomy (the tropical zodiac) – are intrinsically independent. To what extent this was grasped by Ptolemy – in particular regarding the long-term consequence of adopting the tropical zodiac as the standard astronomical frame of reference, thus signifying the gradual spatial displacement between the tropical and sidereal zodiacs on account of precession – is unknown. Although Ptolemy lacked the conceptual framework and the vantage point of modern astronomy, it was theoretically possible for him to anticipate the future spatial dislocation of the tropical zodiac in relation to the background of the stellar constellations that is apparent now that the vernal point is located in the region of the Western Fish of the constellation of Pisces, i.e. now that the displacement between the tropical and sidereal zodiacs amounts to some 25° (almost one complete zodiacal sign).

As the tropical zodiac is still used as a coordinate system in modern astronomy, the uncovering of the line of descent from the solar calendar of the Babylonians to the tropical zodiac reveals the indebtedness of modern astronomy to its origins in Babylonian astronomy. Even if Euctemon arrived at his solar calendar (underlying the tropical zodiac) independently of the Babylonian solar calendar, the line of descent *as a principle in the history of astronomical ideas* is nevertheless apparent, i.e. that Babylonian astronomers were the first to conceive of expressing the sun's yearly motion in declination in the form of a solar calendar. We shall probably never know if Euctemon derived his solar calendar from that of the Babylonians, but we can at least honor the achievement of Babylonian astronomers as being the first to conceive of such a solar calendar, just as this thesis honors their great achievement in defining the original zodiac: the sidereal zodiac.

¹ MUL.APIN, a series of astronomical texts on two tablets, means “the plow star” – named according to the initial words on the first tablet. MUL.APIN stems from the seventh century B.C. but contains observations that were made much earlier. The solar calendar of MUL.APIN consists of a schematic year of twelve months, each 30 days long, such that the equinoxes and solstices fall on the 15th day of the months I, IV, VII, and X. A correspondence is evident between the solar calendar and the zodiac: the zodiac consists of twelve signs each 30° long, corresponding to the solar calendar of twelve months each 30 days in length.

² In the MUL.APIN solar calendar the equinoxes are placed on the 15th day of the months I and VII and the solstices on the 15th day of the months IV and X, whereas in Euctemon's solar calendar the equinoxes are located on the *first* day of the months I and VII and the solstices on the *first* day of the months IV and X. This is a new principle in relation to the Babylonian solar calendar. This new calendar principle introduced by Euctemon is mirrored in the definition of the tropical zodiac, in which the vernal and autumnal points are placed at 0° Aries and 0° Libra and the summer and winter solstitial points are located at 0° Cancer and 0° Capricorn. As discussed in footnote 4, it was probably Hipparchus (second century B.C.) who brought about the transformation of Euctemon's *temporal* solar calendar into the *spatial* coordinate system of the tropical zodiac. In contrast, according to Hipparchus the Greek astronomer Eudoxus (fourth century B.C.) defined the vernal and autumnal points to be at 15° Aries and 15° Libra and the summer and winter solstitial points to be at 15° Cancer and 15° Capricorn. This definition by Eudoxus corresponds exactly to the solar calendar from MUL.APIN (see footnote 3).

³ The ecliptic is the apparent path of the sun through the center of the zodiac. The original zodiac with twelve signs, each 30° long, specified by the Babylonians – in which Aldebaran is located at 15° Taurus and Antares at 15° Scorpio – is called the *sidereal zodiac*, since it is defined in relation to the stars (sidereal means “of the stars”), in order to distinguish it from the *tropical zodiac*, which is defined in relation to the vernal point. The sidereal zodiac and the tropical zodiac both comprise the same ecliptic coordinate system of twelve signs, each 30° long. However, whereas the sidereal zodiac is defined in relation to the stars, the tropical zodiac is defined in relation to the vernal point, which is equated with 0° Aries as the zero point of the tropical zodiac. Note that if there was a perfect correspondence between MUL.APIN's solar calendar and the zodiac (see footnote 1), the vernal point would have to be located at 15° Aries, since Aries as the first sign of the zodiac corresponds to month I and in the Babylonian solar calendar the vernal equinox was placed on the 15th day of month I (as with Eudoxus' definition, see footnote 2). However, in System A of Babylonian astronomy the vernal point was located at 10° Aries and in System B at 8° Aries. From this some researchers concluded that the Babylonians already knew about the slow movement of the vernal point (“precession of the equinoxes”) backwards through the constellations – one sign (30°) in 2160 years, i.e. 1° in 72 years – and that they observed the position of the vernal point in the constellation of Aries and thus determined its location at that time to be 10° Aries (System A) or 8° Aries (System B).

⁴ It is generally assumed that Hipparchus was the first to use the tropical zodiac. In his *Commentary on the Phaenomena of Aratus and Eudoxus* Hipparchus used a variety of coordinate systems, but he did not use the ecliptic coordinate system of the tropical zodiac in this work. The evidence that Hipparchus used the tropical zodiac as a coordinate system is inconclusive. The most important evidence is provided by Ptolemy's remarks in *Almagest VII*, 2 concerning Hipparchus' measurements of the longitudes of the stars Regulus and Spica. However, the possibility has to be considered that Ptolemy himself converted Hipparchus' measurements into the ecliptic coordinate system of the tropical zodiac. There is also the statement by Columella (first century A.D.) in *De re rustica IX*, 14 that Hipparchus placed the solstices and equinoxes in the first degrees (that is, at 0°) of the signs of the zodiac, i.e. that he placed the vernal point at 0° Aries, which defines the tropical zodiac. It is an assumption based on such remarks made by Ptolemy and Columella, rather than evidence from Hipparchus himself, that he, after having discovered the precession of the equinoxes, realized the importance of the ecliptic as a coordinate system and then compiled a star catalog using the ecliptic coordinate system of the tropical zodiac – presumably in the (no longer extant) star catalog said to have been compiled by Hipparchus as mentioned by Pliny in *Natural History II*, 95 and attested indirectly by Ptolemy in the *Almagest* with his references to Hipparchus' interest in observing the positions of the fixed stars. It would seem that Hipparchus probably introduced the tropical zodiac into Greek astronomy. What is definitely known about the tropical zodiac is that it is the standard ecliptic coordinate system that was used by Ptolemy in the second century A.D. and which – following Ptolemy's example – was used in astronomy thereafter.