A COMPARISON OF ASTRONOMICAL TERMINOLOGY, METHODS AND CONCEPTS IN CHINA AND MESOPOTAMIA, WITH SOME COMMENTS ON CLAIMS FOR THE TRANSMISSION OF MESOPOTAMIAN ASTRONOMY TO CHINA

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Abstract: Mesopotamia and China have long traditions of astronomy and celestial divination, and share some similarities in their approach to these subjects. Some scholars have therefore argued for the transmission of certain aspects of Mesopotamian astronomy to China. In this paper, I compare four aspects of ancient astronomy in these cultures in order to assess whether there is any evidence for transmission. I conclude that the similarities between Chinese and Mesopotamian astronomy are only superficial and there is no evidence for the transmission of Mesopotamian astronomy to China.

Keywords: Chinese astronomy, Mesopotamian astronomy, celestial divination, mathematical astronomy, transmission.

1 INTRODUCTION

An interest in the movement and appearance of the Sun, Moon, planets and stars can be traced back in contemporary written sources to at least the Old Babylonian period in Mesopotamia (first half of the second millennium BC) and to the Shang Dynasty in China (mid to end of the second millennium BC). In Mesopotamia, Old Babylonian cuneiform tablets contain omens drawn from the appearance of lunar eclipses (Rochberg, 2006) and schematic lists of the length of day and night throughout the year (Hunger and Pingree, 1989: 163-164). In China, references to astronomical phenomena such as eclipses and comets appear on the so-called 'oracle bones' (Xu et al, 1989; Xu et al., 1995). Except for so-called 'star-clocks' and related astronomical material from ancient Egypt, no *contemporary* writings on astronomical subjects are known from other cultures this early.

Although cuneiform texts containing astronomical material are preserved from all periods in the second and first millennium BC, material is very scarce until the Late Babylonian period (ca. 750 BC to AD 100), with the vast majority of texts coming from the last four centuries BC. A similar situation holds for China: after the Shang Dynasty oracle bones we only have a very few documents containing astronomical records (principally the *Zhushujinian* 竹書紀年 "The Bamboo Annals" and the *Chunqui* 春秋 "The Spring and Autumn Annals") until the second century BC. After this time we have an extensive and continuous tradition of astronomical writings contained within the 25 *Zhengshi* 正史, generally referred to in English as the "Dynastic Histories", and many individual books on astronomical topics, down to modern times.

The plentiful supply of original sources, albeit often not yet translated into a Western language (but see Pankenier et al., 2008; Xu et al., 2000), makes Chinese and Mesopotamian astronomies attractive for comparative studies. Indeed, very soon after the decipherment of cuneiform astronomical and astrological texts had been undertaken by scholars such as A.H. Sayce, J. Epping, and F.X. Kugler, Western scholars began to compare Chinese and cuneiform astronomical texts. In particular, C. Bezold (1919) in an paper entitled "Sze-ma Ts'ien und die babylonische Astrologie" published in *Ostasiatische Zeitschrift* in 1919 compared Mesopotamian astrological omens with astrological portents given in the *Shiji* 史記 written by Sima Qian 司馬遷 around the turn of the first century BC. He claimed that there were striking similarities both of form and content and since the Babylonian sources he was using dated mainly to the seventh century BC put forward the proposition that the idea of a system of celestial divination originated in Mesopotamia and was transmitted to China. Bezold's frequently-cited study has recently been critically analysed by Pankenier (2014) who has shown that Bezold's claims cannot be supported.

In the following decades, other Western historians took up the idea that some Chinese astronomical and astrological ideas and techniques originated in Babylonia. For example, H. Chatley, writing about Chinese astronomy in a wide-ranging review paper entitled "Ancient Chinese Astronomy" published in the first volume of the *Occasional Notes of the Royal Astronomical Society* in 1939 remarked that:

> After the Bactrian contacts with China one might expect some transmission of astronomical ideas from the West. Although there is no

> record of such in the Chinese histories until the third century A.D., it is a fact that many foreign curiosities entered China from about 40 B.C., and we find in A.D. 25 Liu Hsin [Liu Xin] producing an astronomical treatise, *The Three Principle Calendar*, which far excels its predecessors for accuracy and system, and antedates Ptolemy's *Almagest* by over 100 years. (Chatley, 1939: 66).

Later in the same paper he continues

> To the historian of astronomy there are questions of originality and parallelism of development, or, alternatively, the importation of ideas from the West. Scholars are divided as to the extent of early foreign importations, but it seems quite certain that some ideas and a few figures filtered through to China from Chaldea and Greece in the fourth century before the Christian era, and again in the first century. After the introduction of Buddhism in the first century A.D. there can be no doubt as to the inflow of Indian ideas, but the community of notions as to the twenty-eight mansions between India and China in, say, the eighth century B.C. leaves little doubt as to indirect contact at an earlier date. (Chatley, 1939: 71).

Chatley's view is that there likely was transmission of astronomy from Mesopotamia to China and probably also from India to China (perhaps tellingly, he does not consider the possibility of transmission in the opposite direction). In particular, Chatley links one of the key developments in Chinese mathematical astronomy, the *Santongli* 三統曆 "Triple Concordance Calendar" devised by Liu Xin 劉歆 in the first century AD, with western influence. Recent scholarship has shown this system of mathematical astronomy to be firmly within the tradition of Chinese astronomy (Sivin, 1969). Nevertheless, further claims for Babylonian influence on Chinese mathematical astronomy have been made (Jiang, 1988).

Joseph Needham in the section of his monumental *Science and Civilisation in China* concerning astronomy also postulates Babylonian influence on the development of early Chinese astronomy. In particular he posits a Babylonian origin for the system of *xiu* 宿 'lodges' (Needham, 1959: 254-256). Again, more recent scholars have argued for an indigenous Chinese origin for the *xiu* system (Chen and Xi, 1993).

The year before Needham's section of astronomy was published, H.H. Dubs took a different view in an paper on early Chinese astronomy published in the *Journal of the American Oriental Society*. Dubs' conclusion (1958: 298) was that "… down to at least Han times, then, Chinese astronomy was largely an indigenous development." Nevertheless, works have continued to appear, both by Western authors and by scholars in China, which have claimed a Babylonian origin for parts of Chinese astronomy.

Evidence for the transmission of astronomy from one culture to another is often hard to prove. Even contemporary sources can be deceptive in claiming a foreign origin for an idea in order to add to its creditability. For example, in several Greek and Latin works we find scientific ideas and methods attributed to the antiquity of Egypt, when they are clearly nothing of the sort. The similarity of astronomical methods may or may not indicate a common origin. For example, very similar approaches to the use of cycles to predict eclipses (or rather the syzygies at which eclipses are *possible*), are found in Babylonian sources (Steele, 2000) and in Mayan codices (Lounsbury, 1978), but it is historically impossible that these are related. In order to propose the transmission of astronomical methods from one culture to another it is necessary to be able to demonstrate an historical context that points towards such transmission having taken place in other areas of learning. Furthermore, in cases where there is direct evidence of the transmission of astronomical knowledge, when this transmitted astronomy is assimilated into an existing astronomical tradition it inevitably changes, sometimes even at quite a conceptual level. For example, the Babylonian zodiac was a band through which the planets travelled, but the Greeks transformed it into a great circle on the celestial sphere (Steele, 2007). Clear evidence of transmission can often only be demonstrated for non-trivial numerical parameters, especially when they are given with high precision.

The purpose of this paper is to compare selected astronomical concepts, terminology and methods in Chinese and cuneiform sources and to consider whether such comparisons provide any evidence for the transmission of astronomy from Babylonia to China. I have chosen four topics to discuss: celestial omens, the language used to describe eclipses, systems of positional measurement in the heavens and mathematical astronomy.

2 CELESTIAL OMENS AND ASTROLOGY

Beginning in the mid-thirteenth century, Shang Dynasty oracle bones attest to the early adoption of divination as a practice in China (Figure 1). A heated poker would be inserted in a drilled hole on the back of a polished animal bone or turtle plastron producing a pattern of cracks. These cracks would then be interpreted by a diviner and the results of the divination, along with observed verifications, would then be recorded on the bone. Astronomical references in the oracle bones appear only in the observations that are the results of the divination. For evidence of the practice of interpreting events in the heavens themselves as omens, we must move into the first millennium BC.

The earliest extensive source for Chinese cel-

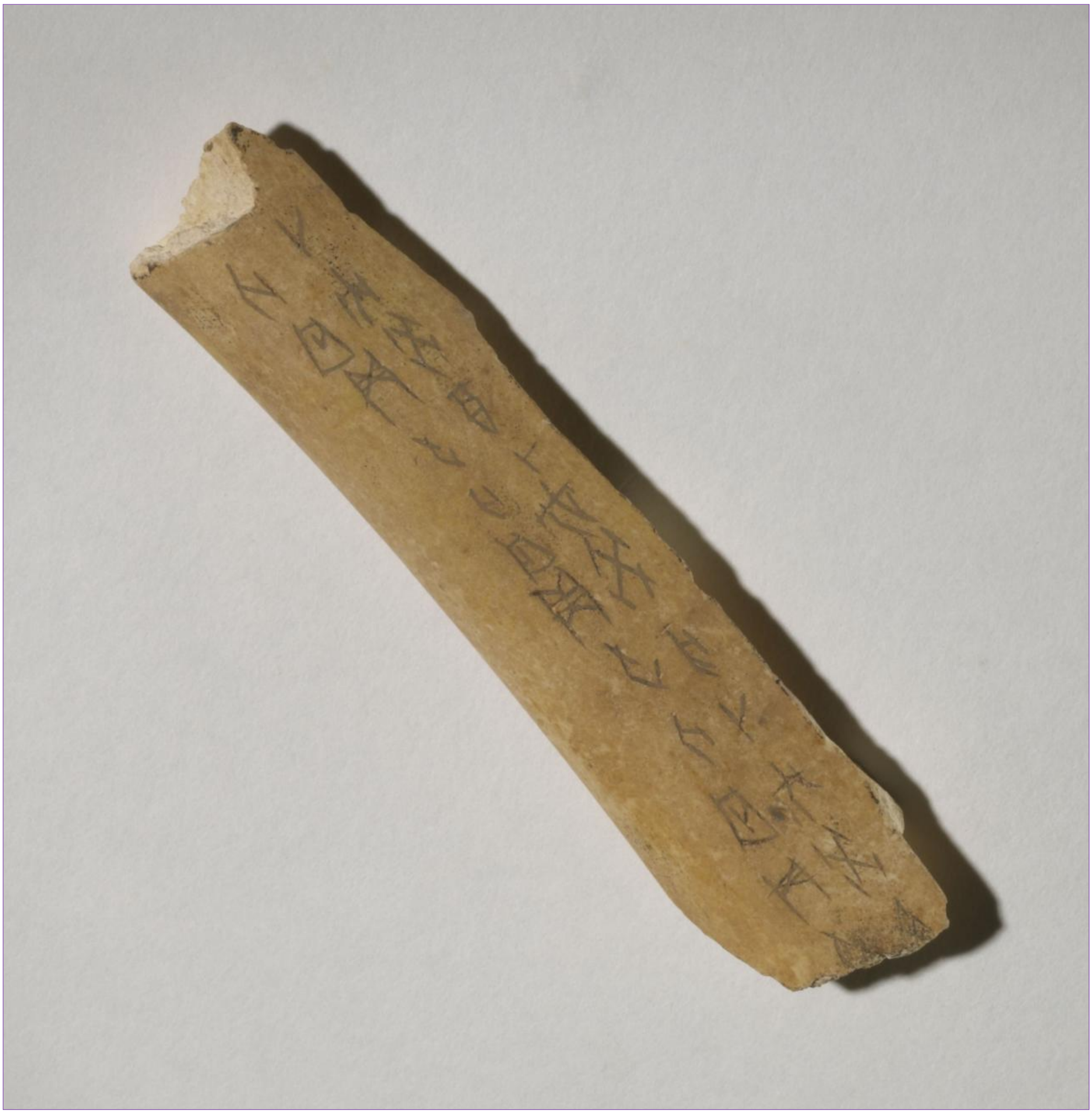

Figure 1: A Shang Dynasty oracle bone (© Trustees of the British Museum).

estial omens is the *Shiji* compiled by Sima Qian around the turn of the first century BC. Chapter 27 of the *Shiji* is a treatise on *tianguan* 天官 ('Celestial Offices'; an annotated translation is given in Pankenier, 2013). Later dynastic histories usually call this subject *tianwen* 天文 ('Heavenly Pattern Reading'). In modern Chinese *tianwen* refers to the subject of astronomy. In ancient and medieval China, however, the term is perhaps better translated as 'observational astrology' since it is the study of observations of celestial phenomena and their interpretation as portents. The investigation of the motions of the celestial bodies and the development of methods to predict the positions of the Sun, Moon and planets and their resulting phenomena such as eclipses, is part of the study of *li* 曆 'calendrical astronomy', or what would be commonly called in the history of Western astronomy 'mathematical astronomy'.

Although written in the seventh century AD, the *tianwen* treatise of the *Jinshu* 晉書 is typical of the style of the *tianwen* treatises in the *Shiji* and later dynastic histories. The whole treatise, Chapters 11 to 13 of the *Jinshu*, has been translated into English by Ho Peng Yoke (1966). It contains discussions of cosmological theory, astronomical instruments, stars and constellations, and accounts of observations of astronomical phenomena together with their astrological interpretations arranged by type of phenomena. For example, an observation of a solar eclipse in AD 260 is reported as follows:

> A solar eclipse occurred on a *i-yu* [*yi-you*] day [i.e., 22 of the sexagesimal cycle], the first day

in the first month of the 5th year (of the same reign period [i.e., the reign period given above]. According to the prognostications of the *Ching Fang I* [*Jing Fang Yi*] whenever a solar eclipse falls on an *i-yu* day it presages that the Emperor will lose his power to his ministers and that the Minister of War will revolt against him. During the fifth month the crime of Ch'eng Chi [*Cheng Ji*] was committed. (*Jinshu* ch. 13; Ho, 1966: 155-156. Comments by the present author in square brackets).

Frequently, the author of the *tianwen* treatises will link an observed celestial portent with an event here on Earth. In the example just cited, the author links the observation of a solar eclipse with the assassination of the Emperor by Cheng Ji 成濟.

All celestial portents in China are directed towards the Emperor and his Government. An Emperor only governed through the mandate of heaven and it was believed that unexpected events in the sky were heaven's way of criticising the rule of the Emperor, warning him that his rule would be extinguished unless he improved his conduct. Crucially, only unexpected celestial events presaged real danger and so the ability to predict an event in advance removed much of the portent from its occurrence. Thus, more easily-predictable lunar eclipses were of far less astrological importance than their harder to predict solar counterparts, as is made clear in the *Shijing* 詩經 "Book of Odes":

That this moon is eclipsed is but an ordinary matter; but that this sun is eclipsed—wherein lies the evil. (Karlgren, 1950: 100).

Because all astronomical portents were directed towards the Emperor, there was a clear link between astronomy and politics in China (Eberhard, 1957). The recording of astronomical events was very often politicised, as is shown in this example from the *Houhanshu* 後漢書:

The sun was eclipsed in the 22nd degree of *tung-ching*. *Tung-ching* is the mansion [lodge] in charge of wine and food, the duty of the wife: 'It will be theirs neither to do wrong nor good, only about the spirits and the food will they have to think.' In the winter of the previous year, the (Lady) Deng had become empress. She had the nature of a man, she participated in and had knowledge of affairs outside of the palace, therefore Heaven sent a symbol. During that year floods and rain damaged the crops. (*Houhanshu* 27; Beck, 1990: 162).

From Mesopotamia we have two primary sources for celestial omens: compilations of celestial omens, principally the canonical omens series *Enūma Anu Enlil*, and omens cited by the scholars employed as advisors to the Neo-Assyrian Kings Essarhaddon and Assurbanipal. In both cases the omens are written as conditional clauses with the protasis generally preceded by the DIŠ sign, either to be read as a logogram for the Akkadian word *šumma* 'if' or, as suggested by Erica Reiner, as simply a paragraph marker. Linking the protasis and the apodosis is the conjunction *-ma*.

The tablets containing omen compilations are generally set out very rigidly so that the same signs lie under one-another in successive lines. This emphasizes the schematic nature of the omen compilations, in which all possibilities of a particular kind of phenomena are listed. For example, here is an excerpt from a collection of Venus omens edited and translated by Reiner and Pingree (the systematic nature of the list is easier to see in the cuneiform so I include an edition of the Akkadian text here with the translation):

[MUL *dil-bat ina*] ITI.N[E KUR-*ha* ŠÈG.MEŠ (*ina* KUR) GÁL.MEŠ *ub-bu-tú* GAR-an]
[MUL *dil-bat ina*] ITI.KIN KU[R-*ha* ŠÀ KUR DÙG-*ab*]
[MUL *dil-bat ina*] ITI.DU$_6$ KUR-*ha* SA[L.KÚR.MEŠ *ina* KUR GÁL-MEŠ EBUR KUR GIŠ]
[MUL *dil-bat ina*] ITI.APIN KUR-*ha* KUR [SAL.KALA.GA DIB-*bat*]
[MUL *dil-bat ina*] ITI.GAN KUR-*ha* SU.K[Ú ŠE *u* IN.NU *ina* KUR GÁL]

[If Venus rises in] Month V: [There will be rains in the land, there will be …]
[If Venus rises in] Month VI: [The land will be happy]
[If Venus rises in] Month VII: [There will be hostility in the land, the harvest will prosper]
[If Venus rises in] Month VIII: [Hard times will seize] the land
[If Venus rises in] Month IX: [There will be] famine [of barley and straw in the land]

(Sm.1480+1796, 5–9; Reiner and Pingree, 1998: 146-147).

Just as we saw for the Chinese celestial portents, the omens apodoses of Babylonian celestial omens always refer to the country as a whole. The only individual mentioned in apodoses is the King, as his fate was tied to that of the land. Again, as in China, celestial omens were at times of major political importance. For example, astronomical omens are one of the most frequently-discussed topics in the correspondence between the Neo-Assyrian kings and their scholars, and some of the scholars tried to use the omens as the means to put forward their own political opinions. The scholar Bel-ušezib in particular frequently wrote letters to the King which go far beyond the mere interpretation of celestial omens. For example, after sighting a meteor, Bel-ušezib takes this as an opportunity to present his views about a forthcoming military campaign to the King:

To the king of the lands, my lord: your servant B[el-ušezib]. May Bel, Nabû and Šamaš bless the king, my lord!

> If a star flashes like a torch from the east and sets in the east: the main army of the enemy will fail.
> If a flash appears and appears again in the south, makes a circle and again makes a circle, stands there and again stands there, flickers and flickers again, and is scattered: the ruler will capture property and possessions in his expedition.
> If the king has written to his army: "Invade Mannea," the whole army should not invade; (only) the cavalry and the professional troops should invade. The Cimmerians who said, "The Manneans are at your disposal, we shall keep aloof"—maybe it was a lie: they are barbarians who recognize no oath sworn by god and no treaty.
> [The char]iots and wagons should stay side by side [in the pass], while the [ca]valry and the professionals should invade and plunder the countryside of Mannea and come back and take up position [in] the pass …
> (LABS 111; Parpola, 1993: 89-90).

Bel-ušezib continues for many lines offering detailed advice on military strategy, none of which is based upon the omens that are ostensibly the subject of the letter.

The development of predictive astronomy in Mesopotamia did not reduce the importance of omens drawn from events that could now be predicted in advance with some degree of accuracy, such as eclipses (Brown and Linssen, 1997), as it did in China. Instead, there is a suggestion that the ability to know in advance that a particular celestial event was forthcoming enabled the Mesopotamians to make advance preparations for ritual responses to the omens.

Although Bezold (1919) claimed that there were direct parallels between a small number of omens found in the *Shiji* and in *Enūma Anu Enlil*, Pankenier (2014) has clearly demonstrated that most of these similarities are due to mistranslations of the Chinese text. Furthermore, even if there were a few similar omens, given that the Babylonian omen corpus contains several thousand individual omens, and that both Chinese and Babylonian celestial divination is primarily concerned with the state, it would not be surprising to find cases in which similar astronomical events predict things like "… the king should not go out …" or "… the army will suffer a defeat …", and there is no need to argue for a common origin to such basic omens.

A new form of astrology developed in Mesopotamia in the late fifth century BC (Rochberg, 1998): personal horoscopic astrology. Horoscopic astrology existed in parallel with the older *Enūma Anu Enlil* tradition of celestial omens in Mesopotamia during the late period. Here we do have clear evidence of the spread of an astronomical tradition from Mesopotamia to China, through Sanskrit intermediaries. The earliest horoscope yet found in an East Asian source is from Japan and for the year AD 1112, although we know several books describing horoscopes from the Tang Dynasty, for example the *Xiuyaojing* 宿曜經 which was translated from an Indian source by Bukong 不空 in AD 759 (Nakayama, 1966).

3 ECLIPSES

The earliest references to eclipses in China are found in the Shang Dynasty oracle bones dating from *circa* 1250–1050 BC. The character used to indicate an eclipse is an early form of *shi* 食 which carries the literal meaning 'to eat' (Xu, Yau and Stephenson, 1989). This character in its standard form continued to be used to indicate an eclipse of the Sun or Moon throughout Chinese history, along with its related homophone *shi* 蝕, formed by the addition of the radical 虫. The use of a character with the meaning 'to eat' suggests that the phenomenon of an eclipse was thought to be caused by something eating the Sun or Moon. Mythological explanations of eclipses along these lines are common throughout the world.

In China, the idea of a creature eating the eclipsed body influenced the terminology employed to describe eclipses and these became standard technical terms. For example, a total eclipse is usually indicated by *ji* 既. The literal meaning of *ji* is 'to complete, have done' and it marks a completed action (Schuessler, 2007: 298); it seems likely that *ji* refers to a total eclipse having been fully eaten (cf. Stephenson, 1997: 223). Other terms used by astronomers in describing eclipses are more prosaic: *kui chu* 虧初 'loss begins', *shen* 甚 'greatest' and *fu man* 復滿 'return to fullness' are generally used to refer to the beginning, maximum phase and end of an eclipse respectively.

In Late Babylonian astronomical texts eclipses are always referred to using the logogram AN.KU_{10} to be read in Akkadian as *attalû*, 'eclipsed', and apparently always to be understood as a technical term. Related Akkadian words such as *adāru* 'to become worried, upheaval', have been shown by Goetze (1946) to be secondary, drawn from the association of eclipses with portended upheaval on Earth. There is no evidence of any mythological explanation for the language used to denote an eclipse. Eclipse myths did exist in Mesopotamia, however. For example, in the sixteenth tablet of the incantation series *utukkū lemnūti* seven demons are said to encircle the Moon during an eclipse, covering the Moon completely (Geller, 2007: 252). But this myth is not reflected in the language used to describe an eclipse.

Although eclipse mythology did not inform the choice of language used to describe eclipses in Mesopotamia, apotropaic rituals did. The period of maximum phase of an eclipse is customarily referred to in Late Babylonian astronomical texts using the logogram ÍR to be read as the Akkadian word *bikītu* 'weeping, lamentation' (Huber and de Meis, 2004: 14). This refers to the ritualised performance of drums and the reciting of laments during the eclipse. For an example of a text describing an eclipse ritual, see Brown and Linssen (1997).

4 POSITIONAL MEASUREMENT IN THE HEAVENS

Defining the position of a body in the heavens is an essential part of astronomy. There are many ways in which the position of a celestial object can be measured. For example, it is possible to measure the distance between one body and another body along the straight line that connects them; alternatively, one could measure the altitude of a body above the horizon and combine this with a measure of its azimuth along the horizon to produce a coordinate pair; or one could measure a pair of coordinates in the sky in some invisible reference system. The choice of one system of measurement over another may be a reflection of the cosmological framework in which one is working, or simply a matter of convenience, depending upon what instruments are available to help in the task.

Throughout Chinese history the main system for defining the position of a celestial object employed the *xiu* 宿 'lodges'. The *xiu* are a division of the sky into 28 zones defined by a determinative star. The zones are unevenly distributed around the celestial equator and fixing their widths was a continuing task for Chinese astronomers throughout the ancient and medieval periods. According to Pankenier (2013), the origin of the *xiu* arose from observations of the Moon's daily motion, and prior to the 5th century BC there were only 27 lodges, 360/27 being closer to the lunar sidereal period. It was only after the 5th century that lodges were regularized to 28 so as to be evenly divisible into 4 cardinal palaces of 7 lodges each. By the Han period at latest the lodges were linked to the celestial equator, called *chidao* 赤道 'red road'.

The celestial equator was taken as the reference system for almost all of Chinese astronomy. Within the various calendrical systems of mathematical astronomy, solar, lunar and planetary motions were always calculated along the equator, although as early as the first century AD the problems with doing so had been noted by Jia Kui 賈逵 in a memorial submitted to the Emperor:

> Your servant has previously submitted a memorial pointing out that when Fu An and his colleagues used the Yellow Road [= the ecliptic] to measure the [positions of] sun and moon at half and full moons, they were mostly correct. But the astronomical officials, who all used the Red Road [= the celestial equator], were not in agreement with the sun and moon … The Red Road is the middle of Heaven, and is 90 *du* from the pole. It is not the path of the sun and moon, and [the effect alleged above] is because one has used such an incorrect standard to measure the sun and moon, and missed the real motions. (Cullen, 2000: 359-361).

Jia Kui is correctly pointing out that the Sun and Moon do not move along the celestial equator. The Sun moves along the *huangdao* 黃道 'yellow road', the ecliptic, and the Moon and planets move along paths running above and below the ecliptic. Nevertheless, the ecliptic only played a secondary role in Chinese astronomy, and all movements were translated into (much more complicated) movements relative to the equator.

The terms used to refer to the equator and the ecliptic, 'red road' and 'yellow road', may have their origin simply in the coloured lines drawn on star maps during the Han period to indicate the equator and ecliptic (Sun and Kistemaker, 1995). The orbit of the Moon was often called *baidao* 白道 'white road'.

Measurements of positions in the sky used the angular measure *du* 度. A *du* was defined by equating the number of days in a solar year with one complete revolution of the heavens. Thus a *du* corresponds to about 360/365.25 degrees. The actual angular extent of a *du* varied at different periods as different lengths of the solar year were adopted in the different caledars. For example, in the *Sifenli* 四分曆 promulgated during the Eastern Han, there were 365 1/4 *du* in a circle, whereas in the *Xuanshili* 玄始曆 used during the Northern Liang, there were 365 1759/7200 *du* in a circle (year lengths taken from Yabuuti, 1963: 459).

The angular measure *du* was only used for measurements parallel to the equator. For other distances, such as those perpendicular to the equator, linear measures such as *chi* 尺 'foot' or its multiple, *zhang* 丈 '10 feet', were used (Cullen, 1996: 41). As we will see, a similar distinction between east-west and north-south measurements appears in Late Babylonian astronomy.

In contrast to its importance in Chinese astronomy, the celestial equator does not feature directly in Mesopotamian astronomy. Indeed, there is no term corresponding to the equator. However, the concept of the daily rotation of the sky and stars that cross a meridian at the same moment is found in several aspects of Mesopotamian astronomy, in particular with the concepts of *ziqpu* stars. Several texts contain lists of simultaneously culminating stars and/or lists of the time intervals between the culminations of certain stars. A statement at the end of one *ziqpu* star list notes that

> [A tota]l? of 12 leagues of the circle of (those that) cul[minate] amidst the stars of the Path of [Enlil] [British Musuem 38369+ ii' 20–21; Horowitz, 1994: 92).

This implies that the full circuit of *ziqpu* stars corresponds to 12 *bēru* 'leagues' or 360 UŠ '(time) degrees', but does not refer to the celestial equator.

Figure 2: A Babylonian cuneiform tablet listing the zodiacal constellations in which the Sun is located each month (© Trustees of the British Museum).

In the Late Babylonian period, celestial positions are generally recorded in one of two systems: using distances *e* 'above' or SIG 'below' (and occasionally *ina* IGI 'in front of' or *ár* 'behind') one of the so-called Normal Stars used as reference markers in the sky; or as positions within the zodiac. Positions relative to the Normal Stars are normally given in units of KÙŠ 'cubits' and their subdivision SI 'fingers', where there were 24 SI in a KÙŠ during the Late Babylonian period (at earlier times there were generally 30 SI to a KÙŠ). As their name suggests, KÙŠ and SI are primarily spatial units, not angular measures. The directions 'above', 'below', 'in front of' and 'behind' correspond roughly to measurements in an ecliptical coordinate system. However, as the direction of motion of the Moon or a planet through the zodiac is more or less indistinguishable from running parallel to the ecliptic over short time-scales, it is quite possible that the Babylonians conceived of these directions as being along a planet's path and at right angles to that path (Swerdlow, 1998).

The movement of the Moon and planets through the sky takes place in a narrow region of stars in what are called 'zodiacal constellations'. In the early astronomical compendium MUL.APIN the eighteen constellations through which the Moon, Sun and planets pass are listed. By the fifth century BC, an abstract system of twelve equal length zodiacal signs had been developed out of these eighteen constellations (Figure 2). The position of the Moon, Sun or a planet could now be given as so many UŠ 'degrees' within a zodiacal sign, where each zodiacal sign contained 30 UŠ. The twelve zodiacal signs therefore make up 360 UŠ.

The zodiac was used in both observational and theoretical astronomy by the Babylonians. In the theoretical astronomical texts it functioned in a way similar to an ecliptical coordinate system, but there is evidence that the Babylonians themselves did not conceive of it in this way.

For example, although positions within zodiacal signs, equivalent to celestial longitudes, were given in UŠ, measurements up or down within the zodiacal band were generally given using the KÙŠ-system. The UŠ and KÙŠ systems were strictly convertible with 1 KÙŠ taken to be 2 UŠ, but making the choice to use two different units suggests that the Babylonians were not thinking in terms of a coordinate system, but of two separate measurements (Steele, 2007).

Although the Babylonians used the zodiac, they did not apparently consider the zodiac to be necessarily linked to the ecliptic. Indeed, there appears to be no concept of the ecliptic within Babylonian astronomy. Instead, we find that the paths of the Sun, Moon and planets are defined as being within individual paths (*mālak*) which have widths; for example in a procedure text concerning Jupiter:

> … in the width of the path … At first station ½ cubit it is high. At second station ½ cubit it is low. (British Museum 36680 + dupl.; Steele, 2005).

Each path has a middle known as DUR MÚRUB 'the ribbon/band of the middle', and upper and lower boundaries. For the Moon we have several texts which detail the upper and lower boundaries of its path, giving their distances above and below each Normal Star (Steele, 2007). The position of the Sun, Moon or planet could be given as the number of degrees within a zodiacal sign, and the height or depth above or below the middle of its path. This system is very close to an ecliptical coordinate system, such as that found in ancient Greek astronomy, but is conceptually and in some measure practically different.

5 MATHEMATICAL ASTRONOMY

Considerable effort was exerted in China and Babylonia to the development of mathematical astronomy. In early China, the tradition of mathematical astronomy is attested in a few manuscript sources such as the *Wuxingzhan* 五星占 and in the *li* 曆 'calendar' treatises of the dynastic histories. The main focus of early Chinese mathematical astronomy is the determination of the day of the beginning of each month and intercalation in the luni-solar calendar. Other phenomena calculated in Chinese mathematical astronomy are eclipses and the synodic phenomena and motions of the five planets. The same set of astronomical phenomena were the focus of Babylonian mathematical astronomy.

The main tool of both early Chinese and Babylonian mathematical astronomy is the identification and use of astronomical cycles. Cycles provide the means for predicting an astronomical phenomenon based upon a previous occurrence of that phenomenon. For example, the synodic phenomena of Venus repeat on approximately the same day in a luni-solar calendar, and at approximately the same position amongst the fixed stars, after 8 years. Furthermore, the knowledge that this phenomenon will take place 5 times during that 8 year period allows the mean date of all occurrences of this phenomenon by simply repeatedly adding 8/5 years onto the date of the first observation. This basic approach is used widely in early Chinese mathematical astronomy (Sivin, 1969) and in Babylonian 'goal-year' astronomy (Steele, 2011), both for the planets and for eclipses (Aaboe, 1972). However, the way in which the cycles are used differs in the two astronomies. In Chinese mathematical astronomy, the mean period between two successive phenomena derived from the cycle is repeatedly added onto an initial date, usually many thousands of years in the past, known as *liyuan* 曆元 'system origin' on which it is assumed that all astronomical cycles begin. By contrast, in Babylonia, there is no equivalent to the 'system origin' and each cycle operates separately, generally starting from a fairly recent observation or calculation of the phenomenon (Figure 3).

The subdivision of the synodic arc of the planets and the velocity of the planet in each part of its synodic cycle is a common topic in both Chinese and Babylonian astronomy. For example, the *Wuxingzhan* includes statements such as the following:

> When Great White [Venus] comes out in the west, it moved 1 *du* and 187 parts in a day. After 100 days its motion becomes slower, and in a day [it moves] 1 *du* so as to wait for it for 60 days. Then its motion becomes slower still, so that in a day it moves 40 parts, and in 64 days it goes in in the west. That is 224 days in all. (*Wuxingzhan* 132; Cullen, 2011b: 246).

This section describes the synodic cycle of Venus as an evening star (Cullen, 2011a). Beginning at its first evening visibility, it moves at a velocity of 1 *du* and 187 parts per day for 100 days, after which it moves at 1 *du* per day for 60 days, and then slows its motion further to 40 parts per day for 64 days before its last evening visibility. Similar discussions may be found in Babylonian astronomical texts; for example, in a Jupiter procedure text we read:

Figure 3: A Babylonian cuneiform tablet containing reports of observed and predicted lunar eclipses arranged in 18-year cycles (© Trustees of the British Museum).

> From setting (last visibility) to appearance (first appearance) it moves 0;12,30 per 'day'. After the appearance for 30 'days' it moves 0;12,30 per 'day'. [For 3 months it moves 0;64,40 per 'day', then it is stationary. For 4 months] it moves backwards 0;4,10 per 'day', [then it is stationary]. (British Museum 34081+ Obv. III 24–25; Ossen-drijver, 2012: 255).

Although there are similarities in the presentation of the schemes for the subdivision of the synodic arcs of the planets in the Chinese and Babylonian texts, on closer scrutiny the two systems are in fact very different. This difference arises in large part because the Chinese system concerns the motion of the planets through the 28 *xiu*, essentially an equatorial system, whereas the Babylonian texts concern the motion of the planets parallel to the ecliptic. Thus, the 'motion per day' of a planet refers to the motion measured in different directions in the Chinese and Babylonian systems, making it extremely unlikely that one system was derived from the other system.

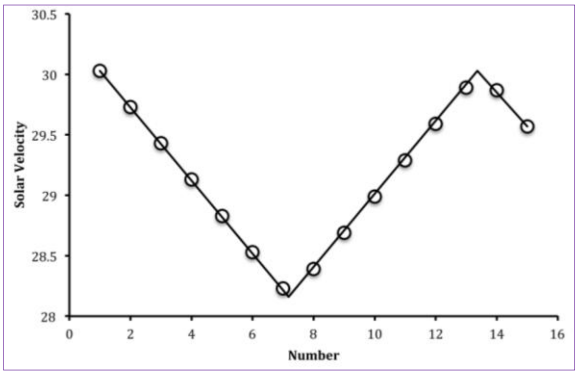

Figure 4: The Babylonian System B zigzag function for the sun's velocity along the ecliptic. Note that the independent variable is the number of the phenomena not the month of the year.

Jiang (1988) has noted apparent similarities between the Babylonian System B model for solar motion and the model for the Sun's motion found in the Chinese *Huangjili* 皇極曆 system of the seventh century AD. Both systems use piecewise continuous linear functions to represent the solar velocity: a linear zigzag function in the Babylonian System B model and a more complicated system employing several zigzag functions in the *Huangjili* (Figures 4 and 5). Jiang concludes that:

> The sudden appearance of these new methods such as the quadratic difference form and linear zigzag function in China in the 6th-7th centuries A.D. seem not to be accidental phenomena. For example, the 12 Babylonian signs of the zodiac appeared in Chinese documents of the Sui Dynasty (581-618 A.D.). Therefore, it is very possible that in the 6th century A.D. some Babylonian astronomical theories were known to the Chinese and accepted by traditional Chinese astronomy. (Jiang, 1988: 831).

Historically, it is not impossible that certain aspects of Babylonian mathematical astronomy could have been transmitted to China via India in the middle of the first millennium AD; along with the zodiac, the tradition of horoscopic astrology entered China by this route. However, the

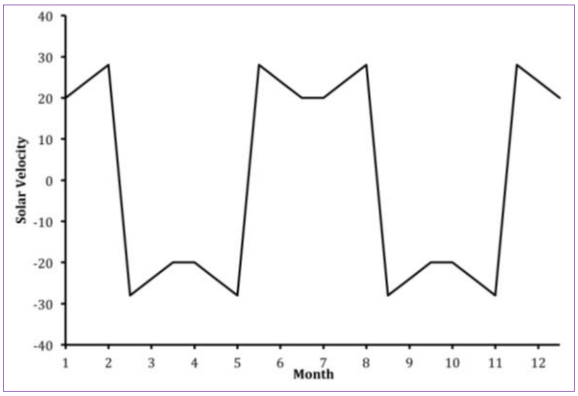

Figure 5: The solar velocity function in the Huangjili (based upon Jiang, 1988: table 2). Note that the solar velocity is calculated along the celestial equator, and the independent variable is the month.

zigzag function is a very basic mathematical tool used to represent variable phenomena—perhaps the most basic—and we should not be surprised to find that it was developed independently in different astronomical traditions. There are further problems with the conclusion that the Chinese solar motion function is based upon the Babylonian System B function. First, the Babylonian function operates with a non-integer period whereas the *Huangjili* function is much simpler in employing an integer period. Secondly, the *Huangjili* function is not a true zigzag function varying linearly between a maximum and a minimum, but rather a piecewise continuous function made upon several linearly-varying sections (Jiang, 1988: Figure 2). It therefore seems very unlikely that there is any dependence of the *Huangjili* solar model on the Babylonian one.

6 CONCLUSION

The aim of this paper has been to compare a small selection of astronomical terms and concepts in Chinese and Mesopotamian astronomy. Although one must be cautious in drawing conclusions regarding the possibility of transmission of astronomy from one culture to another based upon this study, I believe a few remarks can be made. First, it is clear that independent traditions can be very similar, but that this is not evidence for the dependence of one tradition on the other. For example, historically and textually I see no evidence that Chinese celestial divination originated in Babylonia; nevertheless, in both cultures the heavens were used to provide portents, and in both cases these portents were at times exploited for political purposes. Similarly, mathematical astronomy both in Babylonia and in early China dealt with many of the same astronomical phenomena (eclipses, the synodic phenomena of the planets, and the determination of the lunar calendar) and relied upon the use of cycles, but the way that the cycles were used to predict these phenomena differed. Rather than providing evidence for the dependence of Chinese astronomy on Babylonian astronomy, these similarities, such as they are, suggest instead that there are a limited number of astronomical phenomena which are amenable to being modelled without the use of complicated mathematical analysis, and that there are only a limited number of ways to model them. The fact that similar phenomena were modelled using similar methods completely independently by the Mayans lends support to this conclusion.

Finally, there were clear differences between how the Babylonians and the Chinese conceived of celestial measurement—unsurprisingly, given their different cosmologies. Although this would not by itself preclude the transmission of astronomical knowledge from one culture to another, it would make it significantly harder and does, I think, place the onus on historians claiming the transmission of Babylonian astronomy to China to explain how this problem was overcome.

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