

Examination of early Chinese records of solar eclipses

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Abstract

The earliest Chinese historical text that contains systematic records of solar eclipses is the *Spring and Autumn Annals*. In historical periods before the Spring and Autumn period (i.e. the Xia, Shang and Western Zhou Dynasties), solar eclipse records are vague and sporadic. Although numerous scholars have investigated these records in the past two thousand years, it has been rather difficult for them to reach final conclusions. With recent advancements both in astronomical computation and in historic chronology, there has been significant progress in the study of the alleged early Chinese records of solar eclipses. These records include the reference to the solar eclipse of the Three Miao and of Zhongkang in the legends of the Xia dynasty, the expressions such as "three flames ate the Sun", "the Sun and the Moon were eclipsed" and "the Sun was zhi" in the oracle-bone inscriptions of the Shang Dynasty, and the passages of "the sky became extremely dark", "the day dawned twice" and "the Sun was eclipsed" in the literature of the Zhou Dynasty.

Keywords: history of astronomy, solar eclipse, ancient astronomical records, early Chinese history

1 INTRODUCTION

Among various early Chinese astronomical records, that of the solar eclipse (henceforth simply referred to as 'eclipse') was the most complete one and occupied a special position. This was not only because an eclipse, especially a total one, was so spectacular that people were frightened, but also because it was a warning to the Emperor – for the Sun was the symbol of the Emperor according to traditional astrological theories. When an eclipse occurred, the Emperor would normally eat vegetarian meals, avoid the main palace, perform rituals to rescue the Sun, and, sometimes, issue imperial edict to take the blame on himself. Moreover, in order to compile and issue reliable calendars (which was one of the most important governmental affairs during the imperial times), eclipses had to be observed regularly, because they could verify the accuracy of the calendars. Therefore, systematic observing and recording of eclipses, although part of feudalist superstitious rites, was required for scientific research into the calendar during imperial times in China.

The extant systematic early Chinese records of eclipses are from the Spring and Autumn period (770–476 BC). In the *Spring and Autumn Annals*, the history of the state Lu, thirty-seven eclipses are recorded. The loss of eclipse records from the Warring States period (475–221 BC) and the Qin Dynasty (221–206 BC) is severe. From the Western Han Dynasty (206 BC – AD 23) to the end of the Ming

Dynasty (AD 1368–1644), however, such records are complete. Their format, which is rather simple and regular, is as follows: on a certain sexagesimal date of a certain month of a certain year, the Sun was eclipsed. Generally, there is not much information in these records. By the Qing Dynasty (AD 1644–1911), the eclipse records are not only complete, but also include details of the magnitudes and the times of the eclipses. However, studies have shown that these data were predications rather than actual records of observations.

The eclipse records before the Spring and Autumn period – so-called early Chinese eclipse records – are vague and sporadic. In the study of these records, there are problems such as how to understand and interpret the original texts and how to determine whether they are eclipse records and, if so, what kinds of eclipses were recorded. Furthermore, the questions of how to narrow down the chronological period for a particular eclipse record and what method of astronomical computing to adopt are two common problems in this field.

The problem of determining the chronological period for an early Chinese eclipse record is caused by the lack of clear temporal information in these records. In an early eclipse record, if there were a specific date that could be converted to a precise corresponding Gregorian calendar date, it would be a very simple matter to identify the eclipse listed in the record. Unfortunately, the fact is that these early records

normally do not contain specific dates; in a record, there may only be a king's name, or a month number and a date without the king's name. Even if a king's name appears in such a record, it is still rather difficult to narrow down the chronological period for the record, because the generally-accepted earliest precisely-determined date in Chinese history is 841 BC. The length of the reign of each king before that date remains undetermined. As a result, even if a record contains the year of a king, there is no way to directly convert that year to the corresponding year in the Gregorian calendar. As a matter of fact, the main purpose of the study of these early eclipse records has been to establish specific absolute dates for early Chinese history.

Of course, an historian may put forward a general chronological period for an eclipse, based on historical and/or archaeological evidence he or she deems credible. But because eclipses are periodic and repetitive, during this general period a number of eclipses may be possible candidates for such a record. In order to narrow down the period for an event, researchers have to find as much information as possible, such as the date, time and magnitude of the eclipse, and so forth, from relevant records. Such data can serve as the basis for the historian to pinpoint the actual date of an eclipse, but they are often vague, even contradictory. Accordingly, for a particular eclipse, this may result in suggested dates that vary wildly. This is the main cause for divergent results in the study of early Chinese eclipse records.

Recent progress with regard to the dating of early Chinese eclipse records is documented in the report of the Xia-Shang-Zhou Chronology Project, which was published in 2000 (Expert Group..., 2000). In this report, there is a chronological table that provides specific dates for each king of the Western Zhou and Late Shang Dynasties, and approximate starting years for the Xia and Early Shang Dynasties. These dates are the result of a long-term co-operate investigation involving many different disciplines, only one of which was astronomy. This report is undoubtedly an important reference for those wishing to study early Chinese eclipse records.

There is great uncertainty in calculating the details of early eclipses, because of the problem of applying modern astronomical computing methodology to eclipses that occurred thousands of years ago. The main source of error originates from \dot{n} and c , which are both coefficients of square terms for time. Accordingly, the error increases rapidly when the eclipse is distant from the present, which makes the region where a total eclipse could be seen move in an east-west direction. Currently, the error of parameter c is about ± 3 , which would lead to a movement of ± 5 degrees in longitude of the region where a total eclipse could be observed at the beginning of the first century AD. Such movement would increase to ± 20 degrees in the twentieth century BC, which certainly affects the occurrence and magnitude of an eclipse in an extreme way. It is only in the past 20 years that this problem has been given due attention by scholars.

The effect of parameter \dot{n} is similar to that of parameter c , and the general relation between them can be expressed as $0.92\Delta\dot{n} = \Delta c$ (Stephenson and Morrison, 1995). In ILE (Improved Lunar Ephemeris), which is based on the Brown Theory and has been adopted in the field of astronomy for a long time, \dot{n}

and c are specified as -22.44 and 29.95 , respectively. These two values are generally used in eclipse cannons (e.g. Mucke and Meeus, 1983) and in software used for computing eclipses. In recent years, there has been remarkable progress both in determining \dot{n} by various modern methods and in studying c through early astronomical records. In the study of early astronomical records, the value of \dot{n} and that of c are specified as -26 and 30 (or 31), respectively (Liu, 1994; Pang *et al.*, 2002; Stephenson and Morrison, 1995; Zhang and Han, 1995). Obviously, the range from 28 to 34 for c is worth discussing.

2 ECLIPSES OF THE XIA DYNASTY

The contemporary written records of the Xia Dynasty (ca. 2070–1600 BC) have not yet been discovered. Most events of the Xia Dynasty known today are from texts compiled in the Eastern Zhou (770–221 BC) and Western Han Dynasties. Before the Eastern Zhou, how those events were transmitted remains unknown. Therefore, both the clarity and reliability of alleged eclipse records of the Xia Dynasty are not satisfactory at all. It is understandable that at that time, people may have been unable to accurately describe and classify eclipses. As a result, although an eclipse might cause great chaos among people, this astronomical phenomenon would not be recorded specifically as an eclipse. The situation for early eclipse records in other countries was similar.

2.1 The Alleged Eclipse of the Three Miao

The three Miao were a group of people who lived at the beginning of the Xia Dynasty. It is said that there was an eclipse related to the rebellion of these people. The reference to this alleged eclipse in the "Against Aggressive Warfare" chapter of the *Mozi* reads as follows:

In ancient times, the three Miao tribes rebelled massively. Heaven ordered them to be killed. The demoniac Sun rose at night. It rained blood in three mornings. A dragon appeared in the temple. Dogs cried in the markets. In summer, there were floods, and earth cracked until water gushed forth. The five grains mutated. The people were thus greatly frightened. Gaoyang thus issued an order in the Dark Palace. Yu himself held the auspicious command from the heaven to attack the Miao.

This event is cited in other texts as well: it is mentioned in the *Kaiyuan zhanjing* that "... the Sun rose at night." In the *Miaochao zi*, it is recorded that "... the three Miao rebelled massively, the demoniac Sun rose at night." According to these texts, this event occurred before the great Yu founded the Xia Dynasty.

Pang (1996) has proposed that both "... the Sun rose at night" and "... the demoniac Sun rose at night" refer to the phenomenon of a double dusk. When a total or near-total eclipse takes place around sunset, it suddenly becomes dark; several minutes later, when the total eclipse is over it becomes bright, and then becomes dark again (like what normally happens at dusk). If ancient people regarded the first darkness caused by the eclipse as natural dusk, the bright sky immediately after would be the unusual appearance of the Sun at night. If Pang's interpretation is accepted, it would be possible, by way of calculating the date of that eclipse, to determine an absolute date for the era of the great Yu, an important point in Chinese history.

Pang (ibid.) further claims that this eclipse and sixteen other solar and lunar eclipses in early Chinese records provide the skeleton of the chronology from 841 BC back to the start of the Xia Dynasty. Moreover, these early records of solar and lunar eclipses corroborate each other, thus providing important data for research into the long-term change of the Earth's rotation.

Based on the *Bamboo Annals*, Nivison and Pang (1990) have suggested that Yu's reign during the Xia Dynasty dated between 1914 to 1907 BC. During that period, from the region of the three Miao (which is to the south of the Yangtze River, to the west of Lake Poyang and to the east of the Hengshan Mountains) there was indeed an eclipse that could have caused the 'double dusk' phenomenon. It was an annular eclipse with the greatest magnitude of 0.97–0.99, and it occurred on 1912 September 24 BC, which was the third year of Yu.

Liu Ciyuan (2001) points out that, if "the Sun rose at night" is identifiable as a solar eclipse, it could be an eclipse that caused either a double dusk or a double dawn. As a result, it is essential to research the eclipse over an even longer period and to take the uncertainty of the various parameters into serious consideration. By adopting an approach similar to that used when researching the double dawn—which will be explained below—and taking a larger range for c (say from 28 to 35), Liu found six possible double dusk eclipses and five possible double dawn eclipses between 2250 BC and 1850 BC. Since the Xia-Shang-Zhou Chronology Project has chosen 2070 BC as the starting year of the Xia Dynasty (i.e. the year when Yu ascended the throne), the total eclipse of 2072 April 29 BC should be the most possible one. When the range for c is 30–33, this was a total eclipse that occurred from the region of the Three Miao at sunset.

It must be acknowledged that the argument that treats "the Sun rose at night" as the reference to an eclipse is rather weak. First of all, all the unusual events mentioned in the *Mozi* could not have happened on the same day. The original text does not specify whether or not the Sun rose at night only once. If it indeed happened more than once, it could not possibly be an eclipse. Second, the reliability of the event is a big question; to any reasonable person, the notion that it rained blood for three mornings and that a dragon appeared in a temple could not possibly be true. How can one be certain that "the Sun rose at night"? Even if one accepts that the quotation is a reference of an eclipse around sunset at dusk, it is not clear in the original text that it was visible from the region of the Three Miao or from the capital of Gaoyang. As a result, there is no firm basis for identifying the eclipse as one visible from the region of the Three Miao, as Pang (1996) did. It seems likely that "the Sun rose at night" in the *Mozi* and other later texts is not a reference to an eclipse.

2.2 The Eclipse of Zhongkang

Zhongkang was the fourth King of the Xia Dynasty. In the "The Punitive Expedition of Yin" chapter of the *Book of Documents*, there is the following passage that may be regarded as a reference to an eclipse:

On the first day of the last month of autumn, the sun and the moon did not meet harmoniously in Fang.

The blind *musicians* beat their drums; the inferior officers and common people bustled and ran about. He and Ho, however, as if they were mere personators of the dead in their offices, heard nothing and knew nothing; — so stupidly went they astray from their duty in the matter of the heavenly appearances, and rendering themselves liable to the death appointed by the former kings. (Legge 1893a: 165-166)

The extant version of this chapter was found in the Eastern Jin Dynasty (317–420). As a result, its authenticity has been suspected to be false. On the other hand, similar passages are found in earlier texts such as *Zuozhuan* (see the text of the seventeenth year of Zhao Gong) and the "Basic Annals of the Xia Dynasty" chapter of the *Records of the Historian*.

This event is specifically recorded as an eclipse in the 'modern text' *Bamboo Annals*:

In his first year, which was ke-ch'ow (26th of cycle, = BC 1951), when the emperor came to the throne, he dwelt in Chin-sin. In his 5th year, in the autumn, in the 9th month, on the day kang-seuh (47th of cycle), which was the first day of the month, there was an eclipse of the sun, when he ordered the prince of Yin to lead the imperial forces to punish He and Ho. (Legge 1893a: 119)

Its content is very clear; this passage includes the date, month, and year of the eclipse. However, the 'modern text' *Bamboo Annals* and the dates given in it are generally regarded as a forgery. It is very likely that these dates have something to do with the calculation of Yixing in the Tang Dynasty (618–907).

In the "The Punitive Expedition of Yin" chapter, the appearance of *shuo*, 'the first day of the month,' *chen*, 'the Sun and the Moon meet,' the dereliction of duty by Xi He (an astronomical officer), and the chaos caused by the frightening astronomical phenomenon make people relate that event to a total eclipse. As a matter of fact, the *Zuozhuan* already relates it to an eclipse, so it has been a tradition to regard the passage as a reference to an eclipse with a great magnitude.

There are, however, some problems with the record of this eclipse. According to the "The Punitive Expedition of Yin" chapter of the *Book of Documents*, it occurred in the third month of autumn. According to the *Zuozhuan*, it took place in the fourth month in summer. Obviously, these are not the same, and the eclipse could not have happened both in the fourth month in summer and in the last month of autumn. Unfortunately, there is no way to determine which one is correct—if in fact one of them is.

Also, although the sentence "the Sun and the Moon did not meet harmoniously in Fang" is often interpreted to mean that the eclipse occurred in Fang, a constellation, it is actually rather difficult to give a satisfactory explanation for this meaning. Wu Shouxian (1998) suggests that it could possibly refer to the co-occurrence of an eclipse and a comet because the character of negative fu and that for a comet were so similar that the character was possibly changed to that of negative fu during transmission.

Since the "The Punitive Expedition of Yin" chapter was once regarded as a chapter of the *Book of Documents*, the most important Chinese classical text, a great amount of research has been conducted on this chapter (e.g. see *Commentaries to the Thirteen Chinese Classics*). On the other hand, there has been research that aims to establish the date of Zhongkang

reign by dating the eclipse. Based on the Dayan calendar (see the "Treatise on Calendar" chapter of the *New History of the Tang*), Yixing of the Tang Dynasty calculated the date of this eclipse. He reached the following conclusion: it occurred on *gengxu* (day 47), the first day of the ninth month of year *guisi*, which was the fifth year of Zhongkang's reign, at the second degree of the Fang. This date corresponds to 2128 October 13 BC in the western calendar. The same conclusion was reached by Guo Shoujing of the Yuan Dynasty (1279–1368), although his calculation was based on the Shoushi calendar (see the "Treatise on Calendar" chapter of the *History of the Yuan*). Li Tianjing of the late Ming Dynasty and Yan Ruoqu of the Qing Dynasty also conducted research on the Zhongkang eclipse with similar approaches. After western knowledge was introduced to the east in the late Ming Dynasty, ancient Chinese classics were introduced to the west as well. Many western and Japanese scholars also carried out research on this eclipse, and their methods of calculation were far superior to those of the early Chinese scholars. For a comprehensive review of these researches, readers are referred to Chen Zungui (1984).

In recent decades, as a result of improvements in and popularization of astronomical computing methods pertaining to eclipses, new calculations have shown that some previous research findings are no longer tenable. Pang's (1987) calculation has the Zhongkang eclipse occurring on 1876 October 16 BC, and this result is in agreement with his historical date for the eclipse of the Three Miao. In addition, it is recorded in the *Xiaojing gouming jue*, an astrological book from the Han Dynasty, that there was a conjunction of five planets in the era of the great Yu. Such a rare event occurred on 1953 February BC, and this date is in agreement with Pang's dates for Zhongkang and the great Yu as well. Saito Kuniji (1992) has carried out a thorough analysis and correction of ancient texts such as the *Bamboo Annals*. He puts the first year of Zhongkang's reign in the period 1921–1881 BC. According to his calculations, there was an annular eclipse visible from the region of Luoyang on 1912 September 24 BC.

Li Yong's (1999) research and reconstruction of the calculation methods used for Guo Shoujing's Shoushi calendar confirm that there would indeed have been an eclipse on the date given by Yixing and Guo Shoujing, but its magnitude would have been very small, which does not match the situation described in the ancient texts. Furthermore, this partial eclipse would not have been visible from anywhere in China.

Wu Shouxian (2000) has prepared a comprehensive and detailed review and analysis of previous studies, and he lists thirteen different dates in regard to the Zhongkang eclipse. Using modern methods, his calculations clarify some misunderstandings resulting from errors and mistakes made by earlier computers. After thoroughly analyzing relevant texts and the astronomical background of those early events, he researched eclipses that were observable from China over a period of three centuries. During the chronological period associated with the Zhongkang eclipse and the Xia-Shang-Zhou Chronology Project (Expert Group ..., 2000), he proposes 2043, 2019, 1970 and 1961 BC as four possible dates for this event.

Since the reference to the Zhongkang eclipse is

recorded in the *Zuozhuan*, one of the earliest Chinese historical texts, it is likely a credible eclipse record. But the information about this eclipse in later texts is neither certain nor complete. As a result, it is still very difficult to calculate the absolute date of this eclipse.

3 ECLIPSES OF THE SHANG DYNASTY

As recently as one hundred years ago, the Shang Dynasty, just like the Xia dynasty, was regarded as legendary. The discovery of oracle-bone inscriptions at Yinxu confirms many historical facts of the Shang, such as the genealogy of the Shang royal house, recorded in early Chinese texts. This has not only solved the controversy of the existence of the Shang Dynasty, but has also dated the inscriptions to the Shang. Based upon the five clear records of lunar eclipses in the Bin-group inscriptions, we are almost certain that there were records of frequent observations of solar eclipses in late Shang as well, although records of solar eclipses identified so far are much less clear than those of lunar eclipses.

3.1 The Alleged Eclipse of the "Three Flames Ate the Sun"

Jiaguwen heji 11506, a plastron of the Bin-group inscriptions of Shang King Wuding, bears a phrase that was translated as "Three flames ate the Sun and there was a big star" by Dong Zuobin. Dong regarded the phrase as a reference to an eclipse. Liu Chaoyang (1945) held the same opinion, and his interpretation of the phrase was as follows: at the dawn of *yimao* (day 52), it was foggy. Three flames ate the Sun, and a big star could be seen. To him, it obviously recorded the phenomenon of an eclipse. The flames actually referred to solar prominences. Later, Liu Chaoyang (1953) dated this eclipse to 1302 June 5 BC, a *bingchen* (day 53) day, and identified the big star as Mercury. Xu Zhentao (1995) identifies this eclipse with the total eclipse at 11:00 a.m. on 1250 March 4 BC, also a *bingchen* day, which was visible from Anyang. If the phrase indeed is a reference to an eclipse, as they claim, it is still difficult to accept these two opinions because the two eclipses they selected happened on *bingchen* rather than *yimao*, as recorded on *Jiaguwen heji* 11506.

Chou and Pang (a talk at International Symposium on Xia Culture, University of California, Los Angeles, 1990) have conducted a detailed examination of the inscription and researched it. They transcribed several characters of the inscription's verification a little differently from Dong Zoubin. Accordingly, they translate the verification as:

The king made prognostication and said, there would be no disaster and rain. From *yimao* to the early morning of next day, three flames ate the Sun, a big star appeared.

Such a change will avoid the difficulty of identifying the eclipse with *bingchen* (53) rather than *yimao* (52). Pang's (2002) calculation equates this eclipse to that of 1302 June 5 BC, which occurred at 10:45 (Anyang local time). The total eclipse lasted six minutes and twenty seconds. Based on this, he further deduces that contemporary $\Delta T = 7.3 \pm 0.3$ hours.

It must be pointed out that the change made by Chou and Pang (1990) is only an unsubstantiated opinion and is not well supported by paleographical evidence. As a result, it is unfortunate that Chou and Pang's (1990) conclusion seems baseless.

Because of the rarity of a total eclipse, and because of the claim that the inscription in question was the first record in Chinese history of solar prominences, a solar eclipse and the accompanying appearance of a star, this inscription has been assigned paramount importance. Since such an interpretation of the inscription was put forward by Dong and Liu, it has been followed by a great number of scholars, both inside and outside China. To some extent, the opinion seems to be the final conclusion and the inscription is generally regarded as a world record, set by the Chinese.

Different interpretations, however, have existed ever since the very beginning of discussions about the inscription. Yang Shuda read the character *xing*, 'star,' as *qing*, 'sunny.' This interpretation is supported by the context of the inscription. Yan Yiping (1989) demonstrated that the phrase *shiri*, 'to eat the Sun,' actually was a noun of time and had nothing to do with a solar eclipse. Most recently, Li Xueqin's (1999:17) new textual research lends further support to Yang Shuda's interpretation.

According to Yang and Li's interpretation, there is no expression such as "three flames ate the Sun and a big star was seen" on *Jiaguwen heji* 11506. This completely discredits the opinion that the inscription is an eclipse record. Because inscriptional evidence shows the expression *shiri* to be a time noun in the Yin oracle-bone inscriptions (see, for example, *tunnan* 42, 624 and 2666), the inscription on *Jiaguwen heji* 11506 must be excluded from eclipse records.

3.2 The Alleged Eclipse of the So-called "The Sun and the Moon Were Eclipsed"

The sentence "The Sun and the Moon were eclipsed" appears on *Jiaguwen heji* 33694, a scapula of the Li-group inscriptions (Figure 1). Relevant inscriptions can be translated as follows:

Divining on *guiyou* (day 10), tested: The Sun and the Moon were eclipsed, it was auspicious.
Divining on *guiyou*, tested: The Sun and the Moon were eclipsed, it was not auspicious.

As to what astronomical phenomenon these two inscriptions actually refer, there are the following options:

- 1) A solar or lunar eclipse occurred. Because there was a lunar or solar eclipse not long ago, the Shang divined whether it was auspicious or inauspicious.
- 2) A lunar eclipse occurred in the daytime on *guiyou*, i.e. the Moon rose with eclipse.
- 3) The day was as dark as night because of the eclipse.
- 4) A solar eclipse occurred at dusk on *guiyou*. The followers of options 3 and 4 read the character *yue*, 'the Moon', as *xi*, 'night'. The commonality among the above opinions is that there was a solar or lunar eclipse on day *guiyou*. Accordingly, its date can be calculated.
- 5) The inscriptional sentence "the Sun and the Moon were eclipsed" is equivalent to "the Sun and the Moon became dark and were eclipsed" in the "Treatise on Astronomy" chapter of the *History of the Han*.
- 6) These two inscriptions were divining whether a solar and a lunar eclipse would occur.

According to these last two options, there was no solar and lunar eclipse that actually occurred on *guiyou*. As a result, there is no base for any calculations. But this still leaves four other options.



Figure 1. Oracle bone: the Sun and Moon were eclipsed

Based on the assumption that a solar eclipse and a lunar eclipse did actually occur in succession, Chen Zungui (1984) has made the following calculations. If the lunar eclipse occurred on *guiyou* or one or two

days before *guiyou* and the solar eclipse happened before this lunar eclipse, the inscriptions could possibly refer to the total solar eclipse of 1230 July 18 BC and a later lunar eclipse. If the solar eclipse happened on *guiyou* or one or two days before *guiyou* and the lunar eclipse was before this solar eclipse, the inscription would possibly refer to either the lunar eclipse of 1230 May 11 BC and the solar eclipse of 1230 May 26 (*guiyou*) BC or the lunar eclipse of 1222 August 3 BC and the solar eclipse of 1222 August 18 (*gengwu*) BC. Chen has cited Dong Zuobin's opinion: that the two inscriptions are records of the lunar eclipse of 1217 May 11 BC and the solar eclipse of 1217 May 26 (*guiyou*) BC.

Xu Zhentao (1995) supports the third option above. According to his calculation, the eclipse was the total solar eclipse, which had a magnitude of 0.92 at 17:00 (Anyang local time) on 1176 BC August 19 (*guiyou*).

Li Xueqin (1999:67) analyzes the contexts of these inscriptions, and argues that the character *ri*, 'the Sun', and *yue*, 'the Moon', actually consist of the character *ming*, 'dawn'. As a result, he interprets them as a reference to an eclipse at dawn. He further provides the following information for the calculation of the eclipse: 1) it occurred in a month when there was a disastrous locust plague; 2) its sexagesimal date was *guiyou*; 3) it happened at sunrise; 4) it was obviously visible from Anyang; and 5) its absolute date was later, but not much later, than those lunar eclipses of the reign of Wuding (i.e. this eclipse would have been in the reign of Zugeng).

Based on the above conditions set by Li Xueqin for this eclipse, Zhang Peiyu (1999) examined eclipses visible from Anyang in the early morning, and dating between 1500 and 1000 BC. He found only one eclipse that met these requirements, and it occurred around 7 o'clock a.m. on 1269 August 27 BC, with a greatest magnitude of 0.65.

Zhang also made calculations relating to the various interpretations listed above. On the basis of his calculations regarding the five lunar eclipses in the Bin-group inscriptions, he presents the following results:

- 1) If those two inscriptions indeed refer to consecutive solar and lunar eclipses, they may be records of the lunar eclipse of 1171 November 6 BC and the solar eclipse of 1171 November 21 (*guiyou*) BC. In this case, the lunar eclipse happened before the solar eclipse. They may also be records of the solar eclipse of 1183 January 12 BC and the lunar eclipse of 1183 January 21 (*guiyou*) BC. In this case, the solar eclipse occurred earlier than the lunar eclipse and it meets the requirement that the Sun set with eclipse.
- 2) If they mean there was a solar eclipse and the day became dark, they may be a record of the total eclipse, visible from Anyang, on 1176 August 19 (*guiyou*) BC.

While the conditions set by Li Xueqin are helpful for the selection of an eclipse for the two inscriptions, he really needs to provide more inscriptional evidence to substantiate them. From the point of view of paleography, Hu Houxuan (1986: 35-36) reviewed previous studies about the two inscriptions and analyzed the two inscriptions themselves. He was correct in pointing out that the symbol for *xi* was not written the same as *yue* in these two inscriptions and that the meaning of *xi* is 'night' in the oracle bone inscriptions. Since a solar eclipse that

occurs at night cannot be seen, the phrase "the Sun and the Moon were eclipsed" could not be read as "the Sun was eclipsed at night." As a result, option four is no longer tenable. Moreover, Hu's (1986: 36) analysis of its context was correct when he stated that "The phrase *gui-you zhen ri yue you shi* is a charge, not a verification, and therefore it is definitely not the record of an actual event." So the two inscriptions might have something to do with an eclipse, but they are not true eclipse records.

The following is another Li-group inscription: "Tested: the Sun was eclipsed." Obviously, the sentence "the Sun was eclipsed" is the predictive claim rather than verification of the inscription. For the same reasons stated by Hu (1986), it is not a legitimate eclipse record.

3.3 The Alleged Eclipse of "the Sun Was *Zhi*"

In the Li-group inscriptions, there are several examples of the phrase "the Sun was *zhi*." One in particular on *Jiaguwen heji* 33710 reads as follows: "On *xinsi* (day 18) tested: the Sun was *zhi*; perhaps, (we will) report to Father Ding." There are three more examples whose dates of divination are *yichou* (day 2), *gengchen* (day 17), and *yisi* (day 42), respectively. The divinatory date of *Jiaguwen heji* 33699 is not legible although Peng (2002) transcribes it as *wuzi* (day 25). The divinatory dates of other examples are lost.

The majority of scholars in the fields of oracle-bone inscriptions and early Chinese astronomy agree that the expression "the Sun was *zhi*" refers to an important astronomical phenomenon, but whether it means that the Sun was eclipsed remains an open question.

It was Guo Moruo who first noted that the pronunciations of the characters *zhi* and *shi*, 'eclipse', were similar and that word *zhi* could be used as a loan word for *shi*. Accordingly, Guo regarded the phrase "the Sun was *zhi*" as reference of eclipse. Chen Mengjia thought that *zhi* might refer to a sunspot or spots. Furthermore, it has been proposed that the phrase may imply that the colour of the Sun changes to red. With the discovery of phrase "the Moon was *zhi*" in the oracle-bone inscriptions, Chen Mengjia's opinion is no longer tenable, because there is no 'moonspot' (or spots).

Li Xueqin (1999:79, 187) has discussed the contexts of these inscriptions. By comparing the meaning of words in relevant inscriptions and building upon recent progress in the field of Chinese paleography, he determines with certainty that the expression "the Sun was *zhi*" is the expression for a solar eclipse in the oracle bone inscriptions. He further argues that Chen Mengjia's other suggestion (that the phrase might relate to the reddening of the Sun) is also untenable.

Zhang Peiyu (1999) has identified five lunar eclipses in the Bin-group inscriptions with five lunar eclipses that occurred between 1201 BC and 1181 BC. As for the above eclipses in the Li-group inscriptions, he has found only one set of eclipses whose dates are comparable to the dates of the five lunar eclipses: the eclipse on *gengchen* occurred on 1198 October 21 BC, that of *xinsi* on 1172 June 7 BC, and that of *yisi* on 1161 October 31 BC. As for the eclipse of *yichou*, he has not yet identified it with any particular eclipse, because of Li's (1999:187) opinion that the Shang diviner was not certain whether an eclipse had actually happened.

Pang (2002), too, has derived dates for those four eclipses: the eclipse of *yichou* happened on 1226 May 6 BC, that of *gengchen* on 1198 October 21 BC, that of *xinsi* on 1172 June 7 BC, that of *yisi* on 1161 October 31 BC, and that of what he transcribes as *wuzi* on 1163 June 27 BC. Obviously, he expanded the time period in his search for these eclipses.

As shown above, more than six decades after Guo, there is not much progress with regard to the decipherment of the bone inscription *zhi*. Some important questions remain unanswered. For example, if *zhi* indeed is a loan word for *shi*, why is *shi* itself used to refer to an eclipse? Why does *shi* not *zhi* appear in early Chinese records of eclipses? Moreover, the calculations for the alleged eclipse records in this section have not produced satisfactory results, because of two main reasons. First, whether or not these inscriptions are true eclipse records remains an open question, and there is no way to guarantee convincing results. Second, as Hu Houxuan (1986) has pointed out, all these inscriptional phrases "the Sun was *zhi*" appear in charge rather than in verification of these inscriptions and they are thus not records of true events. As a result, there is simply not sufficient information for reliable calculations. Considerably more work needs to be done on determining whether these are in fact true eclipse records.

4 WESTERN ZHOU

In the literature of the Zhou Dynasty, there are two unique astronomical phenomena, that is, the double dawn and the sky becoming extremely dark, that might be caused by eclipses with great magnitude. However, historians of the Western Zhou had failed to realize the occurrence of solar eclipses, possibly because of cloudy weather or because the Sun was hidden behind a mountain. Since the Eastern Zhou, the concept of *shuo*, "new moon," has been clearly established, and the prediction of solar eclipses has begun after the Han Dynasty. As a result, phenomena similar to "the day dawned twice" and "the sky became extremely dark" can easily be recognized as eclipses and they no longer appear in texts. The expression of an eclipse in the *Book of Songs* is very clear, but whether it refers to a specific eclipse still remains an issue. Having said that, thirty-seven eclipse records were found in the *Spring and Autumn Annals*, from which the history of systematic and continuous Chinese eclipses began.

4.1 The "Tian-Da-Yi" Eclipse Record

There is the following passage in the *Bamboo Annals* "ancient text":

In the nineteenth year of King Zhao, the sky became extremely dark (*tian-da-yi*). Pheasants and hares were terrified. The King's six armies perished in the Han River.

'Yi' is an ancient character, which means "dark and shadowed" or "dark and windy". Apparently, this "tian-da-yi" event happened when King Zhao led the military campaign against the southern state of Chu. The passage above is cited in other texts such as *Chu Xueji* (Volume 7), *Kaiyuan zhan jing* (Volume 101), and *Taiping yulan* (Volume 907). The military campaign is often mentioned in bronze inscriptions as well, so the reliability of the event is not in question.

The fact is that when a total eclipse reaches its greatest magnitude the sky becomes dark so rapidly that frightened pheasants and hares panic and run about. There may also be a cool wind because the surface of the ground is not heated evenly. Similar situations are often seen in both ancient and modern Chinese and non-Chinese eclipse records. Therefore, "it became extremely dark" is very likely a reference of an eclipse with a great magnitude. As for why it was not recorded as an eclipse, it might be because the sky was overcast that day. At that time, people were unable to determine "new moon day", and needless to say, they could not forecast eclipses. As a result, it did not occur to them that the sky became extremely dark because of an eclipse. This is rather similar to the situation of a double dawn in the first year of King Yi. He Youqi (1989: 119), Takarou Hirasei (1997) and Zhang Wenyu (1998) all point out without further discussion that "it became extremely dark" is a reference to an eclipse.

King Zhao was the fourth king of the Western Zhou Dynasty. The absolute dates of his reign cannot be found in the historical texts, and more than thirty opinions have been proposed thus far. On the other hand, the majority of historians agree that the last year of King Zhao's reign, when the eclipse occurred, was in the period between 1000 and 950 BC (Zhu Fenghan and Zhang Rongming, 1998).

During that period, according to Liu Ciyuan (2002a), there were four eclipses with great magnitude that were visible from central China. They took place in 980 BC (an annular eclipse), 978 BC (a total eclipse), 976 BC (a total eclipse) and 969 BC (an annular eclipse). In his astronomical computations, he adopted the following parameters: $\dot{n} = -26$ and $28 < c < 33.5$. As for the locations of observation, the following two localities were chosen: Jingchu (nowadays Jingzhou in Hubei Province) and Zongzhou (present day Xi'an).

His analyses show that from the region of Jingchu, it would have been possible to observe three out of the four eclipses. These occurred in 980 BC, 976 BC and 969 BC, and their maximal magnitudes were 0.87, 0.94, and 0.93, respectively. Among these three eclipses, the one in 969 BC was also visible from Zongzhou and its greatest magnitude was 0.90. This eclipse could have possibly caused the sky to become extremely dark, thus frightening pheasants and hares. This was further associated with the death of King Zhao and the loss of his six armies. All of these unusual events made it possible that the record of this eclipse was spread and passed down. As for the eclipse in 978 BC, its magnitude was likely not as great. Moreover, the Sun was very close to the horizon – possibly even below the horizon – when the eclipse reached its greatest magnitude. Therefore, it was impossible for this eclipse to have caused the sky to become extremely dark.

Based on the calendar reconstructed from bronze inscriptions and various other sources, the Xia-Shang-Zhou Chronology Project (Expert Group ..., 2000) selects 995 BC as the first year of King Zhao's reign, and 976 BC as the first year in the reign of his immediate successor, King Mu. Therefore, the nineteenth year of King Zhao's reign should be 977 BC. However, there was no eclipse of great magnitude visible from China in that year; the eclipse in the last year of King Zhao's reign was most likely the one in 976 BC, as Liu Ciyuan (2002a) has

shown. This apparent contradiction can be resolved by adjusting the Project's chronological table appropriately. If the reign of King Kang, the king preceding King Zhao, is increased by one year, the reign of King Zhao will be one year later accordingly, which will cause the nineteenth year of King Zhao's reign and the first year of King Mu's reign to be in the same year. Since no bronzes of King Zhao can be used to determine the absolute dates of the chronology of Western Zhou, such an adjustment will not be contradictory to the reconstructed calendar based on extant bronze inscriptions. As a matter of fact, it will not be contradictory to any evidence used in the reconstruction of the calendar by the Project team.

It should be noted that according to the adjustment proposed above, King Mu would have changed the designation of the year when he came to the throne. However, this is not a problem since it was allowed by contemporary practices (Chen Meidong, 2000). In fact, according to the Project's chronological table, both King Gong and Gonghe changed the designation of the year when they came to the throne in the Western Zhou Dynasty. Thus, based on astronomical calculations and results of the Xia-Shang-Zhou Chronology Project, the total eclipse of 976 May 31 BC is the best explanation for the record in the "ancient text" *Bamboo Annals* that "the sky became extremely dark in the nineteenth year of King Zhao". When the value of c is between 28 and 30, according to Liu's calculation, the greatest magnitude of the eclipse visible from the region of Jingchu was as much as 0.94.

In sum, the notion that the sky became extremely dark in the last year of King Zhao's reign is indeed a record of an eclipse, and it can be identified with the eclipse of 976 May 31 BC.

4.2 The "Double Dawn" Eclipse Record

It is recorded in the *Bamboo Annals* that "in the first year of King Yi it dawned twice at Zheng." (Figure 2). Apparently, its literary meaning is that it dawned again after it dawned once, which can be called a 'double dawn'. Zheng, a contemporary place name, was in the vicinity of present day Xi'an city.

The *Bamboo Annals* was discovered in the tomb of King Xiang of Wei of the Warring States during the Western Jin Dynasty. It is an early Chinese historical text which is of paramount importance, but unfortunately has been lost for centuries. However, its record of the double dawn is cited by *Kaiyuan zhan jing* of the Tang Dynasty and *Taiping yu lan* of the Northern Song Dynasty, and appears in other reference books. In the "modern text" *Bamboo Annals*, this event is recorded as:

In his 1st year, which was *ping-yin* (3d of cycle, = BC 894), when he came to the throne, there were two sun-risings in Ch'ing. (Legge 1893a: 152).

This is the only record of a double dawn in the historical texts, and it is often listed in the entry of "sky changes" or "sky cracks" without any detailed discussion. Liu Chaoyang (1944) was the first scholar who pointed out that it was a change in the brightness of the sky caused by a total eclipse. It thus became possible to determine the date of King Yi by calculating the date of the eclipse. Therefore, this opinion was taken very seriously in the field of Chinese history, and based on the calculation of the eclipse, Liu Chaoyang reached the conclusion that the first year of King Yi's reign was 926 BC.

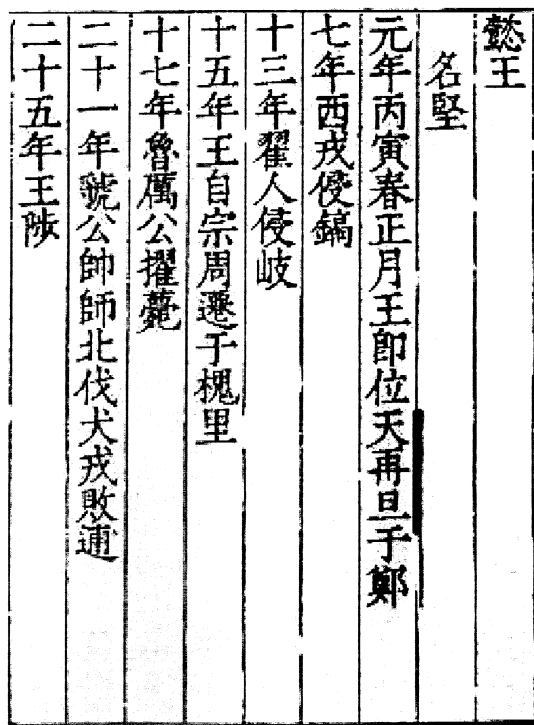


Figure 2. *Bamboo Annals*: double dawn.

Research carried out subsequently has been summarized by Liu Ciyuan (1999). For example, Dong Zuobin has pointed out that the eclipse would need to have occurred around sunrise for it to have caused the phenomenon of a 'double dawn'. Dong proposed that the eclipse was in 966 BC. As for the first year of King Yi's reign, the following alternatives have been proposed: 925 BC, 919 BC, 903 BC and 899 BC. The approach adopted by the majority of historians is this: after determining the date of King Yi's reign on the basis of other chronological data, they selected one eclipse from the cannon of eclipses that was near their date-range for King Yi; but they did not pay much attention to the astronomical calculation of the eclipse. Because of the relatively high frequency of eclipses at this time, this approach has led to different conclusions.

Pang (1988) offers a good explanation of the situation of an eclipse at sunrise. Moreover, he makes use of the most recent astronomical computational methods to revise the calculation of the eclipse. At the end of his investigation, he firmly concluded that the eclipse in 899 BC is the one referred to as the double dawn event during the reign of King Yi.

Stephenson (1992) opposed the opinion that the double dawn was caused by an eclipse for two reasons. First, in his calculations Pang specifies a value of 29.5 for c , and gets the result that the eclipse in 899 BC happened at sunrise at Zheng, which meets the requirement of the double dawn record in the *Bamboo Annals*. However, the correct value of c was thought by Stephenson to be 44.3, which would mean that the eclipse occurred more than one hour before sunrise at Zheng. As a result, it would be impossible to have seen any change in brightness of the sky that could be associated with a 'double dawn' event. Second, the eclipse in 899 BC was annular, and although its magnitude was not very different from that of a total

eclipse, its effect on the human eye would have been quite different. An annular eclipse does not cause the sky to become extremely dark.

After discussing the relevant texts, previous studies and the location of Zheng, Liu Ciyuan (1999a) pointed out that a major shortcoming of the previous studies was the lack of a theoretical explanation and actual observations of the phenomenon. By conducting research into how sky brightness is expressed and the change in the sky brightness at normal sunrise, and by taking astronomical theories on changing sky brightness during an eclipse into consideration, he established a theory of how to calculate the sky brightness during an eclipse at sunrise (Liu Ciyuan, 1999b). He found that the degree of obviousness, or intensity, of the phenomenon of a double dawn at a location is mainly related to the magnitude of the eclipse, the height of the Sun, and the weather.

Given a proper definition of the intensity, all such events can be calculated and illustrated by means of intensity contour maps. The eclipse of 1997 March 9 provided an excellent opportunity to test his theory, and this event was recorded by a network of observers in northern Xinjiang. At eighteen different locations more than sixty observers prepared thirty-five different reports that covered the magnitude of the eclipse, the height of the Sun, and the weather conditions. These reports verified Liu's theoretical calculations. Building on the observations of that eclipse, Liu examined eclipses between 1000 and 840 BC and found that only the eclipse of 899 April 21 BC could have caused a 'double dawn' at Zheng.

After further analysis of the historical background and natural situation of Zheng, Liu (1999c) affirmed that the double dawn in the first year of King Yi at Zheng was a reference to the eclipse of 899 BC. Moreover, astronomical analyses show that, on average, a double dawn at a particular location happens only once in a thousand years. Since the possible range for the first year of King Yi's reign given by historians is about 40 years, the probability of that double dawn occurring at Zheng is only 4 percent. The occurrence of a double dawn with such small a probability thus lends support to the opinion that the recorded double dawn was indeed caused by an eclipse (Liu Ciyuan 2002b).

The excavated bronze Shihu gui is classified as a vassal of King Yi, and it bears a phrase that reads, "On *jiayu* (day 11), which was *jiwang*, 'after full moon,' of the sixth month of the king's first year." The lunar phase of *jiayu* of the sixth month of 899 BC in Chinese calendar was exactly *jiwang*. This is strong collateral evidence for Liu's conclusion (Expert Group ..., 2000). As a result, the identification of 899 BC as the first year of King Yi's reign has been adopted by the Xia-Shang-Zhou Chronology Project as one of the seven datum points in establishing the chronology of the Western Zhou Dynasty.

4.3 The Eclipse Recorded in the *Book of Songs*

A poem in "The Conjunction in the Tenth Month" of the *Book of Songs* includes the following stanzas:

At the conjunction (of the sun and moon) in the tenth month,
On the first day of the moon, which was *sin-maou*
[i.e. *xinmao*, day 28],
The sun was eclipsed,
A thing of very evil omen.

Then the moon became small,
And now the sun became small.
Henceforth the lower people
Will be in a very deplorable case. (Legge
1893b:320-321).

This poem clearly records that there was an eclipse on *xinmao*, which was the first day of the tenth month, and that there was a lunar eclipse not long ago. Throughout Chinese history, scholars have provided an enormous number of commentaries on this record (e.g. see the *Commentaries to the Thirteen Chinese Classics*).

As for this eclipse, it has been dated to the reign of King Li, King You, or King Ping (for references, see Chen Zungui 1984). Astronomers of different dynasties have tried to use different methods to calculate the date of this eclipse. It is recorded in the *New History of the Tang Dynasty* that Yu Kuang of the Southern Dynasties identified it with the eclipse of 776 BC, the sixth year of King You of the Zhou Dynasty. Yixing, who based his calculation on the Dayan calendar, reached the same conclusion, as did Guo Shoujing (see the "Treatise on Calendar" chapter in the *History of the Yuan Dynasty*). Such a result implies that the calendar used in this poem was the Zhou calendar, which is different from the Xia calendar used in other poems in the *Book of Songs*. This has caused some doubts. Recent calculations show that the eclipse of the sixth year of King You was not visible from central China. Accordingly, the eclipse has been identified with the one in the first year of King You's reign, on 781 June 4 BC, or the one in the thirty-sixth year of King Ping's reign, on 735 November 30 BC.

Chen Zungui (1984) has conducted a detailed review of previous studies. After analyzing relevant texts and the historical background of the poem, he does not believe that the month during which the eclipse occurred, in the first year of King You's reign (i.e. 781 June BC), matches the month recorded in the poem. Nor does he believe that the historical situation in 781 BC matches what was described in the poem. Therefore, he inclines to identify the eclipse with one in 776 BC, the sixth year of King You's reign, and points out that there were two visible lunar eclipses that took place in 776 BC, on February 26 and August 21. Moreover, he claims that astronomical events in the sixth year of King You's reign match very well the situation described in the poem.

Zhang Peiyu (1984) has analyzed all solar eclipses during the two hundred year period from 880 to 680 BC, which corresponds to the reigns of King Li, King Xuan, King You, King Ping, King Huan, and King Zhuang. He has found four eclipses around *xinmao* in the tenth month of the contemporary calendar. They occurred on 833 September 5 BC, 797 October 26 BC, 776 September 6 BC, and 735 November 30 BC, but his calculations showed that the first two eclipses were partial and could not be seen from China. The eclipse of 776 BC (in the sixth year of King You's reign) was only visible to the north, and could not have been seen from the capital of the Zhou. As for the eclipse of 735 BC (in the thirty-sixth year of King Ping's reign), this was observable as a partial eclipse from the capital of Zhou, with a maximum magnitude of 0.80. Moreover, the first month of the year was the third month after the winter solstice, which was very close to the Xia calendar (whose first month was the second month after the winter solstice). Therefore, the eclipse of 735 BC was very likely the one recorded in the poem.

Liu Jinyi (1985) argues that, according to Oppolzer's cannon, if ΔT is changed by 3.5 hours, Xi'an would have been part of the region where the eclipse in the sixth year of King You's reign could have been seen. However, modern research has made it clear that such a drastic change of ΔT is impossible.

Liu Ciyuan and Zhou Xiaolu (2002c) have reviewed the *status quo* and the difficulties associated with historical and astronomical studies about the eclipse in the *Book of Songs*. Based on the progress in astronomical computing achieved in recent decades, they present a comprehensive discussion on astronomical factors relating to the eclipse. They tabulated all eclipses that occurred on *xinmao* days from the eighth century BC to the sixth century BC and all eclipses that happened in the tenth months from the reign of King Li to that of King You. Moreover, they discussed astronomical factors such as the magnitude of each eclipse, its possible range of change caused by the uncertainty of calculating, and associated lunar eclipses, in the hope that such information will be helpful for future research into the meaning and background of the poem in the *Book of Songs*.

Although it is generally accepted that the stanza cited at the beginning of this Section is an eclipse record, its identification is still surrounded by controversy. This may have something to do with the nature of the record. After all, it is a poem, and it could be that some information in that poem is not historically correct.

5 POSTSCRIPT

Early Chinese texts are rather brief and abstruse. In addition, the ability of the ancient Chinese to understand and describe astronomical phenomena was limited. As a result, there is great uncertainty with regard to the so-called early Chinese eclipse records. As a matter of fact, apart from the eclipse record in the *Book of Songs*, none of the records discussed above includes accurate terminology for a solar eclipse. For example, what some records describe is only *similar* to the situation during a solar eclipse, and other records are regarded as references of solar eclipses only because certain scholars have claimed that they *are* eclipse records.

In this paper, we call them early Chinese solar eclipses records simply because they have been used as sources of data in the study of solar eclipses. The aim of this paper has been to examine which of the alleged early Chinese solar eclipse records are reliable eclipse records and which are false.

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