

# Astronomy in the Xia-Shang-Zhou Chronology Project

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## Abstract

The Xia-Shang-Zhou Chronology Project was undertaken in order to set up a chronological framework for the Xia, Shang, and Zhou Dynasties in early China. There are 12 Working Groups involved in the Project that focus specifically on ancient astronomical records. Some of these have already reached precise chronological conclusions that have been generally accepted.

**Keywords:** *chronology, ancient astronomical records, history of astronomy – Chinese history*

## 1 INTRODUCTION

China claims a history of 5000 years but precise chronology can only be traced back to 841 BC, the first year of the reign of Gonghe. This date is based on documentation provided by Sima Qian, the great first century BC historian. For a long period historians did their best to refine Chinese chronology, but little progress was made. Then a new opportunity arose thanks to developments in modern science and technology and to new archaeological discoveries. The Xia-Shang-Zhou Chronology Project brought together scholars from archaeology, astronomy, history, and radiocarbon dating in a bid to break the deadlock. After five year's effort, the Project published its initial report (The Expert Group ..., 2000). This is in Chinese, but an English version will be published soon. At its core is a chronological list, which includes approximate dates for the beginning of the Xia Dynasty (2070 BC) and the early Shang Dynasty (1600 BC), and precise commencement dates for the reigns of some kings in the late Shang Dynasty (1300–1046 BC) and every king in the West Zhou Dynasty (1046–771 BC).

There are various astronomical records included in the ancient Chinese literature, and by using modern astronomical methods some of these (but particularly eclipses, and positions of the Sun, the Moon, and the planets) can provide useful information. These sorts of historical astronomical records have also been used in this way in other countries.

The Xia-Shang-Zhou Chronology Project was carried out by forty-four different Working Groups, twelve of which used mainly astronomical evidence. One of the four Project Chairmen, Professor XI Zezong, co-ordinated and led all of the astronomical investigations, which eventually will be brought together in a book. Listed below are the twelve different Working Groups reports and their authors.

- G1. JIANG, Xiao-yuan: *The Star Dahuo in the Three Dynasties and Chronology.*
- G2. XU, Zhen-tao: *Conjunctions of the Five Planets and the Changes of the Dynasties.*
- G3. LIU, Ci-yuan and JIANG, Lin-chang: *A Complementary Study on the War of Sanmiao.*
- G4. HU, Tie-zhu: *Stellar Phenomena in Xiaxiaozheng and Chronology.*
- G5. WU, Shou-xian: *A Re-study of the Solar Eclipse in Shangshu.*
- G6. ZHANG, Pei-yu: *Astronomical Records and Calendar on the Oracle Bones in Shang Dynasty.*
- G7a. JIANG, Xiao-yuan: *Astronomical Events and King Wu's Conquest.*
- G7b. LIU Ci-yuan: *Astronomical Events and King Wu's Conquest.*
- G8. CHEN, Jiu-jin: *Reconstruction of the Calendar of the West Zhou Dynasty from Bronze Inscriptions.*
- G9. LIU, Ci-yuan: *The Double Dawn and the First Year of King Yi.*
- G10. CHEN, Mei-dong: *The Calendar Regulations in the Periods of West Zhou and Chunqiu.*
- G11. SUN, Xiao-chun: *Foreign Astronomical Records in the Period of Xia-Shang-Zhou.*
- G12. NING, Xiao-yu: *Astronomical Computation Center and Data Base for the Study of History.*

## 2 THE INDIRECT ASTRONOMICAL EVIDENCE

Working Group G11 looked at overseas astronomical events during the Xia-Shang-Zhou period. The chronologies of ancient Babylon and Egypt depend largely on astronomical records. Because of precession, astronomical phenomena change slowly from century to century, and records of Sirius rising with the Sun, for example, have been used to push the chronology of Egypt back to the twentieth century BC. The Working Group also examined two possible solar eclipses recorded by the Hittites. A group of records relating to Venus found on excavated clay tablets pushed Babylonian chronology back to the twentieth-nineteenth centuries BC. These astronomical conclusions were based on various assumptions, including the places of observation, the calendars in vogue at that time, and the exact meanings of certain special terms; they also relied on historical and archaeological evidence. However these uncertainties do not invalidate the overall results, and *Chronology of Ancient Civilizations of the World ...*, published in Beijing (Northeast Normal University, 1999), provides a good overview of the findings of this Working Group.

In ancient Egypt, Sirius played an important role in determining the seasons, but in ancient China it was Alpha Scorpii that served this purpose. Known as *Dahuo*, the 'Fire Star', it is mentioned in many ancient Chinese records including:

"In the middle of summer, the day is the longest, the Fire Star transits [at dusk]." (*Shangshu. Yaodian*)

"In the 5th month, Shen stars [Orion] appear [before sunrise], Fire Star transits [at dusk]." (*Xi Xiaozheng*)

"The 7th month, Fire Star flows [to the west]; the 9th month, cloths [for winter] are ready." (*Shijing*)

Working Group G1 discussed the relationship between those phenomena and the times. It was useful to understand the background circumstances, although it was not possible to derive exact chronological results because of the crudeness of these records.

Conjunctions of the five planets were considered as important omens to changes of dynasties, and such records are associated with most early Chinese dynasties:

"At the time of King Yu [founder of the Xia Dynasty] the five planets were strung together like a necklace. They shone as brilliantly as chained jade disks." (*Xiaojing Goumingjue*)

"In the 10th year of King Digui [the last King of Xia Dynasty], the five planets were in disorder, stars fell down like rain." (*Bamboo chronicle*)

"In the 32nd year of King Dixin [the last King of Shang Dynasty], the five planets gathered in constellation Fang." (*Bamboo chronicle*)

"The five planets gathered in constellation Ji before Duke Qihuan became the overlord." (*Songshu*)

"In the 1st year, 10th month of Han Dynasty, the five planets gathered in constellation Jing." (*Hanshu*)

What we are particularly interested in are the first three. Working Group G2 showed the first two events possibly took place in 1553 BC and 1513 BC, and that the third event could not have taken place during this period. Meanwhile, the last two records are obviously wrong because there were no such planetary conjunctions at the times indicated (see Zhang, 1991). In fact this sort of record was often suspect in earlier times because of its strong astrological associations.

*Xi Xiaozheng* is a chapter of *Liji* compiled during the West Han Dynasty, and was considered as a calendral source for the Xia Dynasty. It records a dozen stellar phenomena, including:

"In the 1st month, Ju stars appear [before sunrise]; Shen stars transit at dusk and Dou stars hung."

"In the 3rd month, Shen stars disappear [in the sunlight]."

"In the 4th month, Mao stars appear [before sunrise]; Nanmen stars transit at dusk."

Ancient people used these phenomena to estimate seasons, and it is important also to remember that these phenomena were changing gradually because of precession. Working Group G3 showed that these events occurred throughout the whole Xia-Shang-Zhou period, and that it therefore was not possible to reach any direct chronological conclusions (see Hu, 2000).

King Yu was the first king of the Xia Dynasty. *Muozhi* say "The sun appears in the night before Yu crusaded against the Sanmiao tribe." and Pang and Yau (1996:103) believe this possibly refers to a solar eclipse at sunset. Upon linking related ancient literature and new archaeological discoveries, Working Group G4 was able to discuss the historical background and the geographical location. By using the astronomical 'double dawn' method, and allowing for uncertainty in the rotation of Earth, eleven different solar eclipses in three different centuries were found that matched this record. But we still need more information to confirm this as a record of an eclipse, and the reign of King Yu also needs to be shortened.

*Shangshu* records a horrible event during the reign of King Zhongkang, in the middle of the Xia Dynasty: "On the first day of late autumn, the Chen was not harmonious in constellation Fang, the blind beat drums, junior officers galloped, people ran around..." This famous story has been documented in the literature since the sixth century BC, with most people thinking that it relates to a solar eclipse. Since ancient times, many scholars have tried to identify the eclipse so as to date the reign of King Zhongkang. Working Group G5 carried out a thorough analysis of these earlier investigations (see Wu, 1998, 2000). Thirteen different conclusions contained in them were analysed, and some apparent mistakes were found. The calculations made by these earlier researchers were also analysed (Li & Wu, 1999). Finally, the Working Group reviewed all solar eclipses that occurred during a three-century period, and came up with four possible dates: 2043 BC, 2019 BC, 1970 BC, and 1961 BC.

The calendar in the West Zhou Dynasty is an important chronological base, but we have very little information about it while there are many clues in the succeeding Chunqiu period. Working Group G10 reconstructed the calendar in the Chunqiu period, which is a useful reference for us to understand information from West Zhou. The Working Group also showed that some kings would count their reign from the very first year in which they ruled, while most kings began counting from the following year. Another conclusion of this Working Group was that the 'Jupiter chronology' was only in vogue during the Zhanguo period (Chen, 2000).

### 3 EXACT CHRONOLOGICAL CONCLUSIONS FROM ASTRONOMICAL RECORDS

#### 3.1 Eclipses on the Oracle Bones

Since their initial discovery in AD 1899, a great many oracle bones have been unearthed in Anyang, the capital of the late Shang Dynasty, and the inscriptions on these bones provide invaluable information about this period of Chinese history. Working Group G6 investigated these oracle bones, and astronomy played an important role in their study (see Zhang, 1999). Altogether, about ten records of solar and lunar eclipses have been found. There are usually sexagenary days listed in the records, but the name of the king, the year, and the month are typically absent. A group (Group Bin) of five lunar eclipses was documented by the same powwow, and historians believe that he served King Wuding or a slightly later king. Assuming that the sexagenary days can be continually traced back to that time (we have independent evidence only to 720 BC), many possible combinations were found by computing eclipses that would have occurred during the approximate period of King Wuding's reign. Archaeological and palaeographical investigations also provided useful information, including the relative dating of different oracle bones, but did not produce reliable absolute dates. Date boundaries were set at around 3 a.m. as a result of studying the oracle bones and astronomical history. Under these circumstances, the only possible set of five lunar eclipses was found to date between 1201 and 1181 BC. Table 1 gives the original records and the identified dates, plus the magnitudes and times of maxima (in Beijing Time). These identifications also provide support for the continuation of the sexagenary dating system.

Table 1: The five lunar eclipses of Group Bin and their identifications

| Record  | Date          | Magnitude | Time |    |
|---|---------------|-----------|------|----|
|   |               |           | h    | m  |
| guiwei (20) night Moon eclipsed                 | 1201.7.12 BC  | 0.51      | 00   | 04 |
| [jia]wu (31) night Moon eclipsed                | 1198.11.4 BC  | 0.72      | 22   | 17 |
| jiwei (56) night to gengshen (57) Moon eclipsed | 1192.12.27 BC | 1.67      | 22   | 51 |
| renshen (9) night Moon eclipsed                 | 1189.10.25 BC | 0.51      | 21   | 06 |
| yiyou (22) night Moon eclipsed                  | 1181.11.25 BC | 1.73      | 20   | 16 |

This conclusion has been accepted as a basis for determining the reign of King Wuding, which then became an important reference for other kings of late Shang Dynasty.

In addition, another group (Group Li) of four eclipses has also been identified, but these have not yet been incorporated into the formal findings of the Project.

Finally, we should note that the group re-evaluated the famous "tree flames eat the Sun" event which is typically associated with a solar eclipse, and found instead that it was best explained as a record about the weather (Li, 1999).

### 3.2 King Wu's Conquest

King Wu conquered King Zhou and founded the new dynasty of West Zhou. This was an important event in Chinese history, although the precise date of this event is in doubt. However, it is a key to the Xia-Shang-Zhou Chronology Project. There are quite a number of related chronological and astronomical records, but they are generally concise, vague, even suspect, and at times are contradictory. Moreover, different choices, interpretations, and explanations lead to different conclusions. As a result, previous investigations produced forty-four different conclusions, spanning a 110-year period, and these various papers have recently been brought together and published in a book (Beijing Normal University, 1997). The main astronomical records include:

"The first month, day Renchen [29], it was Pang Siba. The next day was Guisi [30]; King Wu departed from Zhou [state] to crusade against King Zhou [of Shang Dynasty]. Counting from the day Ji Siba of the third month, the fifth day was Jiazi [1] when King Zhou was killed. Counting from the day Jipang Shengba, the sixth day was Gengxu [47] when King Wu prayed at the grand temple of Zhou [state]." (*Wucheng*)

"When King Wu conquered King Zhou, Jupiter was in the constellation Chunhuo; the Moon was in the constellation Tiansi; the Sun was in the constellation Ximu; 'Chen' was in the constellation Doubing; 'the star' was in the constellation Tianyuan." (*Guoyu*)

Other records involve conjunctions of the five planets, a lunar eclipse on day Bingzi (13), and Jupiter and a comet in the east sky. These events do not limit the time strictly. In addition, an inscription on a bronze Ligui possibly mentions Jupiter (in the middle of the sky or in the constellation Chunhuo).

The latest archaeological discoveries compress the possible period to between 1050 BC and 1020 BC (Wang and Xu, 2000). An important initial problem was the terms used for the lunar phase, such as Shengba and Siba, and these have been satisfactorily explained (see the next paragraph). Many astronomical, calendrical, and historical clues imply the event should have taken place in winter, and on this basis the diary (i.e. month, day, and lunar phases) listed in *Wucheng* was analysed and five candidates were found: in 1046, 1041, 1037, 1031, and 1020 BC (Liu, 1999). Then the condition of "Jupiter in constellation Chunhuo" was added, and the only choice of date for King Wu's conquest was 20 January in 1046 BC (Liu, 2001). This conclusion, reached by Working Group G7b, is independently supported by the Bingzi lunar eclipse and other lunar phases mentioned in *Shangshu*. It also accords with most astronomical, archaeological, and historical information, and supports the late Shang Dynasty and later West Zhou Dynasty chronology derived by other Working Groups involved in the Xia-Shang-Zhou Chronology Project. This conclusion has been accepted as a key result by the Project. In fact, Pankenier (1981-1982) arrived at the same date, using other clues. Meanwhile Working Group G7a suggests that the correct year is 1044 BC (Jiang and Niu, 1999).



### 3.3 Bronze Inscriptions and the Kings of West Zhou Dynasty

According to reliable history, the sequence of kings of the West Zhou Dynasty was: Wu, Cheng, Kang, Zhao, Mu, Gong, Yi, Xiao, Yii, Li, Gonghe, Xuan, and You. There are many surviving bronzes from the West Zhou Dynasty, and more than sixty have characters on them that contain the 'four elements': year, month, sexagenary day, and lunar phase. Upon utilizing lunar phases computed by astronomical methods, every single bronze could be limited to several dating possibilities (see the last section). Ideally, combining all sixty bronzes should lead to much stricter limits, and it should be possible to set up the whole chronological system of kings of the West Zhou Dynasty. However, there were major difficulties. The records list only the year and not the name of the king, so we can only roughly assign the inscriptions on each bronze to a particular king on the basis of their form, figure, pattern, and characters. 'Shengba', 'Siba', 'Jiwang' and 'Chuji' are special terms for lunar phase, but their exact meanings have been argued for two thousand years. In addition, there were still some unanswered questions on calendar regulations during West Zhou times (and especially the beginning of the year).

The following examples in Table 2 are useful for an understanding this work, and summarize some of the findings of Working Group G8. In this Table, 'Original Record' includes the name of the bronze, the year, month, sexagenary day (and its sequence number), and lunar phase, while the second column gives the name of the king to whom the bronze possibly relates. After a comprehensive analysis, it should be possible to date every bronze to a particular calendar year BC by correlating the lunar age (i.e. lunar phase) with the original historical record. This is a basic analytical technique for the study of West Zhou chronology, and although many scholars carried out their own investigations of these bronze inscriptions, unfortunately they came up with quite different results. These are collected together in a new book edited by Zhu and Zhang (1998).

Table 2. Some examples of bronze inscriptions

| Original Record   | Associated King   | Interpretation                             | Date BC |
|---|-------------------|--|---------|
| Xiangui: 34th year 5th month day<br>Wuwu(55), Jiwang        | King Mu           | King Mu 34y 5m day<br>Wuwu(55) l.a.17      | 943     |
| Weiding: 9th year 1st month day<br>Gengchen(17), Ji Siba    | Around King Gong  | King Gong 9y 1m day<br>Gengchen(17) l.a.24 | 914     |
| Shihugui: 1st year 6th month day<br>Jiaxu(11), Jiwang       | Around King Yi    | King Yi 1y 6m day Yihai (12)<br>l.a.20     | 899     |
| Mugui: 7th year 13th month day<br>Jiayin(51), Ji Shengba    | Around Yii and Li | King Yi 7y 13m day Jiayin(51),<br>l.a.7    | 893     |
| Shiduigui3: 3rd year 2nd mon. day<br>Dinghai(24), Chuji     | Around King Li    | King Yii 3y 2m day<br>Dinghai(24), l.a.3   | 883     |
| Nizhong: 1st year 3rd month.<br>DayGengshen(57), Ji Shengba | Around Yii and Li | King Li 1y 3m day<br>Gengshen(57), l.a.11  | 877     |

Throughout a synthesized investigation using data drawn from astronomy (Jing, 1999), ancient literature, and palaeography (Wu, 1999), the Project adopted the following interpretation:

- 'Ji Shengba' = crescent to full Moon
- 'Jiwang' = days around full Moon
- 'Ji Siba' = waning Moon to New Moon
- 'Chuji' = the first ten days of every month

Astronomy and the historical literature offered seven vital key points that underpinned the chronology of the West Zhou Dynasty, including King Wu's conquest (1046 BC), the double dawn event (899 BC, see Section 3.4 below), and the first year of Gonghe (841 BC).

Based on the archaeological classification (Wang *et al.*, 1999), the above explanations for the different lunar phase terms and the seven key points, the G8 Working Group reviewed all the bronzes and drew up a chronological list for the West Zhou Dynasty, including the reign of every king. In this way it proved possible to assign dates to most bronzes, including those examples listed in Table 2 (although there were still difficulties with three bronzes). However, this overall result was one of the most important conclusions of the Project, and as we have seen astronomy played an important role in this work.

### 3.4 Double Dawn and the First Year of King Yi

The *Bamboo Chronicle* contains the following record: "The first year of King Yi, the sky dawned twice at Zheng." This has been considered evidence of a total solar eclipse at dawn so that before sunrise the sky became bright, then the eclipse took place and it darkened, and following the eclipse it brightened again, just like a second dawn. Identifying this eclipse would give a date for the reign of King Yi, and previous studies have produced six or seven different conclusions (see Liu and Zhou, 1999b), mainly because there have been inadequate investigations of the physical process involved. On the other hand, Stephenson (1992) has questioned whether this record does in fact signify a solar eclipse record.

The physical process of a total solar eclipse involves three different elements: the brightness change of a normal morning, the actual brightness change during the eclipse itself, and the perceived change in visual brightness as experienced by observers. The intensity of a 'double dawn' can be defined as the change of this visual brightness, so we can draw intensity contours of double dawn on the map for every eclipse. Then we can compute when and where an historical double dawn would have taken place. Generally speaking, this phenomenon takes place at the western end of the central belt of a solar eclipse, and its intensity and geographical area depend on three factors: eclipse magnitude, solar altitude, and the weather (Liu and Zhou, 1999a). What we needed was a practical investigation of our methodology, and by good fortune a total solar eclipse was visible from China on 1997 March 9, with the western end of the central belt located at the northern part of Xinjiang. We arranged for popular observations of this event to be carried out, and sixty people sent us thirty-five different reports from eighteen different locations. As a result, these reports included different eclipse magnitude, solar altitude, and weather details, plus personal comments on visual brightness, which allowed us to fully test our theory and to verify it. We therefore searched for solar eclipses during the period 1000-840 BC and found only one identification at Zheng: on 21 April in 899 BC (see Figure 1). We believe that the *Bamboo Chronicle* double dawn record relates specifically to this eclipse

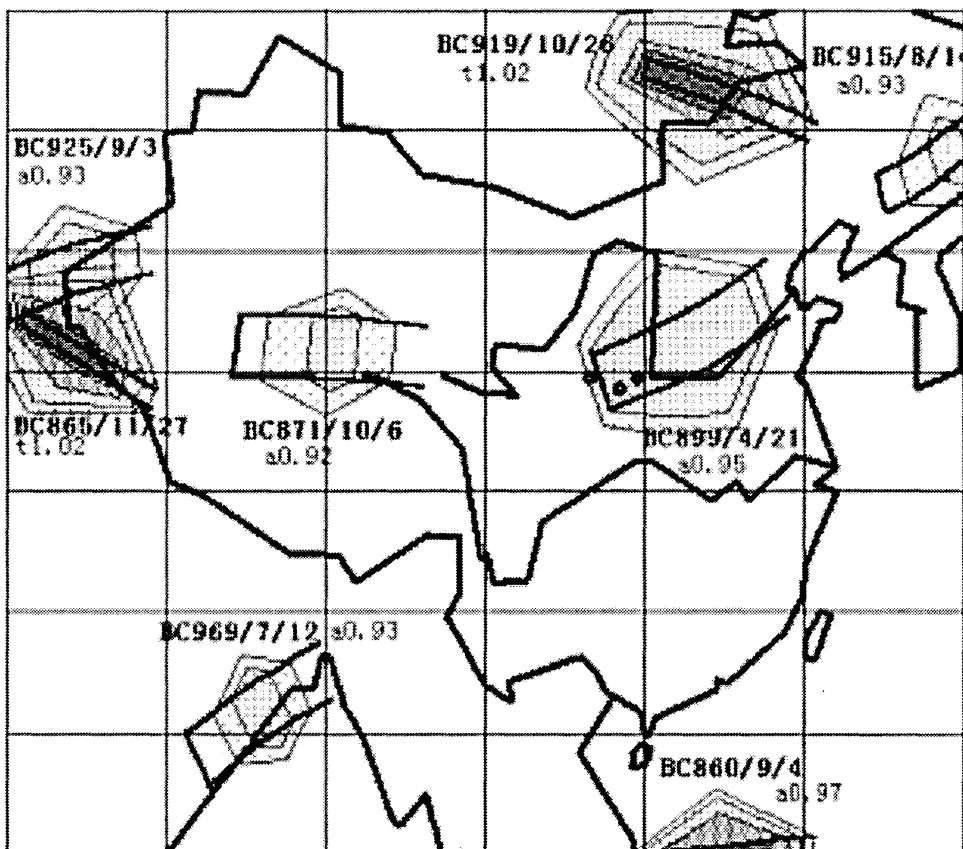


Figure 1. Double dawn events during 1000-840 BC (after Liu, Li and Zhou, 1999)

(Liu, Li and Zhou, 1999), a conclusion that is independently supported by a bronze inscription (The Expert Group ..., 2000). This conclusion has been accepted by the Xia-Shang-Zhou Chronology Project, and is one of the seven key points underpinning the West Zhou chronology system proposed by Working Group G9.

This work strongly supports much earlier conclusions reached by Fang (1975) and Pang *et al.* (1988), both of whom also suggested 899 BC for this event.

#### 4 CONCLUSION

On 2000 November 9 the Xia-Shang-Zhou Chronology Project announced the following chronology list for the three dynasties:

##### **Xia: 2070-1600 BC**

##### **Shang (early): 1600-1300 BC**

##### **Shang (late): 1300-1046 BC**

Pangeng-Xiaoxin-Xiaoyi (1300 BC)

Wuding (1250 BC)

Zugeng-Zujia-Lingxin-Kangding (1191 BC)

Wuyi (1147 BC)

Wending (1112 BC)

Diyi (1101 BC)

Dixin (1075 BC)

##### **West Zhou: 1046-771 BC**

Wu (1046 BC)

Cheng (1042 BC)

Kang (1020 BC)

Zhao (995 BC)

Mu (976 BC)

Gong (922 BC)

Yi (899 BC)

Xiao (891 BC)

Yii (885 BC)

Li (877 BC)

Gonghe (841 BC)

Xuan (827 BC)

You (781 BC).

This list is a useful reference frame for Chinese history, and will be adopted by dictionaries, textbooks, and museums. As a result of future investigations, we expect to make further progress in archaeological discovery, C<sup>14</sup> determination technology, and astronomical computation, and hope that the ancient literature will provide new discoveries and fresh interpretations.

#### 5 ACKNOWLEDGEMENTS

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