

The Present Status of Chinese Study of Solar Eclipses

Ma Liping

National Time Service Center, Chinese Academy of Sciences

18 Lintong, Shaanxi, China 710600

Email: mlp@ntsc.ac.cn

Abstract: Chinese scholars have done lots of work on solar eclipse recorded in historical archives. Two aspects of the present study of solar eclipses are introduced. One is statistic and analysis of solar eclipse records, which contains research of original records and table of solar eclipse. The other is application of ancient eclipses records, mainly in historical chronology and the secular variation of the Earth's rotation.

Key words: records of solar eclipse, China, statistic and analysis, historical chronology, secular variation of the Earth's rotation

0 INTRODUCTION

Great importance was attached to solar eclipse in ancient China. Ancient Chinese astronomers have bequeathed to us the longest series of eclipse observations in the world, mostly for astrological prediction and making exact calendars. With the most complete records, solar eclipse occupies a special place in the various records of celestial phenomena in Chinese history.

Ancient Chinese records of solar eclipse can be divided into three categories (Liu Ciyuan, 2002a):

1) From the Xia Dynasty to the end of the West Zhou Dynasty, relevant records were sporadic and vague. Most of them did not have exact dates or direct descriptions of solar eclipses. Because of their important role in the research in historical chronology and modern astronomy, much attention has been devoted to them. Liu Ciyuan et al. (2003) review the previous research and progress.

2) The extant systematic Chinese records of solar eclipse started from the Chunqiu (Spring and Autumn) period. In the Spring and Autumn, the history of the Lu State, 37 solar eclipses were recorded. Most of the records of the following Warring States Period and the Qin have been lost and those that survive are open to question. From the West Han Dynasty through the end of the Ming Dynasty, solar eclipse records are rather complete. The form of these records is quiet concise and formalized: “year, month, sexagesimal day, the Sun was eclipsed”, with very little other information. However, these records are quite complete and few have been lost. We call these “regular” records of solar eclipse in Chinese history.

3) In the late period of the Ming Dynasty and the whole Qing Dynasty, local annals became common, which often recorded eclipse and other celestial phenomena, especially the splendid appearance of total solar eclipses. Liu Ciyuan et al (Liu Ciyuan and Zhuang Weifeng 1998; Ma Liping, 2004b) show that there are errors in most of those local records.

In this paper, statistic and application of solar eclipse records, two aspects of the present status of Chinese study of solar eclipses, are introduced.

1 STATISTIC (COLLECTION) AND ANALYSIS OF SOLAR ECLIPSE RECORDS

1.1 RESEARCH OF ORIGINAL RECORDS

Mr. Zhu Wenxin is the first scholar who studied all the solar-eclipse records in Chinese history with modern astronomical computational method, and he published the book, *An Examination on History Records of Solar Eclipse* (Zhu Wenxin, 1934). A total of 921 records are sorted out in this book. Zhu investigated and verified these records based on Oppolzer's *Canon of Eclipses* (Oppolzer, 1962). His work created a new and important field in the study of Chinese history of astronomy. Liu Ciyuan and Ma Liping (2008) investigated the book of Zhu Wenxin. The statistic results of the records from various scholars are compared, as well as the eclipse records of the Western Han Dynasty, which contain quite many mistakes, are investigated to continue Mr. Zhu's work.

Chen Zungui (1984) conducted a comprehensive statistics of the past dynasties eclipse records(1,124 items) in his book, *A History of Chinese Astronomy*, which listed reign title, date, sexagesimal day, the corresponding Julian-Gregorian date and the code number of Oppolzer's *Canon of Eclipses*. Furthermore, the solar eclipse records of the pre-Qin period were analyzed. Zhang Peiyu (1975) studied the Records of the Solar and Lunar eclipses in Scripts and on Tortoise-shell or Ox-bones.

In the 1970's, More than 10,000 astronomical records from large number of old books were collected together as a "General Table of Ancient Chinese Astronomical Records", which appeared as an informal publication in 1977. Eventually, it was officially published under the title *General Collection of Ancient Chinese Astronomical Records* (Zhuang Weifeng et al., 1988). Unfortunately, the latter includes only a minority of the material assembled in the table. Liu Ciyuan and Zhuang Weifeng (1998) shows that there are errors in most of those local records.

The Astronomical Records in the archives of the Astronomical Bureau in the Qing Dynasty were analyzed by Bo Shuren(1980).Chen Jiujin(1983) reduced the times of 120 solar eclipses records to hours and minutes, and he analyzed the precision of them. China First Archives and Beijing Ancient Observatory (1996) coedited *A Collection of the Qing Dynasty Archival materials of Astronomy*, including solar eclipse in the archives of the Astronomical Bureau and the Ministry of Rites in the Qing Dynasty. Li Yong et al. (1995, 2001) did some researches on solar eclipse records.

The research group led by Shi Yunli has done many studies on records of solar eclipse, especially the records in the Qing Dynasty. Shi (2000) found an absolute majority of the eclipses recorded in the *Qing-chao Wen-xian Tong-kao* (*Comprehensive study of civilization of the Qing Dynasty*) are predicted results rather than observational reports. Shi et al. (2000) gave a supplement to the collection of eclipse predictions preserved in the astronomical achieves in the Qing Dynasty. Lü Lingfeng and Shi Yunli (2001) analyzed the accuracy of eclipse predictions and observations made during calendar-debating in the late Ming Dynasty. Lü and Shi (2003) found that after the editing of the *LXKCHB(Later Volumes of the Thorough Investigation of Calendric Astronomy)*, the accuracy of solar eclipse predictions is improved and is kept stable until the end of the Qing Dynasty. Xing Gang and Shi

Yunli (2005) analyzed the reliability of the records of solar eclipse from the Han Dynasty and used the records in checking the precision of the system of calendar astronomy in the Han Dynasty. Lü (2006) introduced the eclipse records in historical documents in the Qing Dynasty and the research results about it.

A comprehensive statistics and analyses of solar eclipse records in ancient China have been conducted by our research group, mainly professor Liu Ciyuan. The research contents include solar eclipse records in the early time, the Spring and Autumn period to the Jin Dynasty, the Southern and Northern Dynasties, the Sui, the Tang and the Five Dynasties, the Song Dynasty, *JIN SHI*, *YUAN SHI*, the Ming Dynasty, the Qing Dynasty, and big solar eclipses in the Ming and Qing Dynasties. There are three stages about Chinese ancient solar eclipse records. The early records can only be described as a clue, due to lack of date and exact description of the phenomenon. The official records of solar eclipse are complete and formulaic from the Spring and Autumn period to the Ming Dynasty. We call these “regular” records. Since the Ming Dynasty, many provinces and counties began compile their local annals, which included a large number of records of solar eclipse. Some of them contain vivid and detailed description of total eclipse. But there are many errors in local history records. At the same time, the prediction and records of solar eclipse of the imperial court preserved more complete. Liu Ciyuan (2005) tabulate 938 solar eclipse records of the period from the Spring and Autumn period to AD1500, the middle of the Ming Dynasty. Most of them came from the official Histories. This eclipse table provides the comprehensive information of regular solar eclipse records for historians and astronomy historian. Twenty-Five Histories are Chinese series official history books, the most important Chinese ancient history. They are the main source of Chinese records of solar eclipse. All the past dynasties attached great importance to these historical collations. In recent years, Liu Ciyuan attended the “Revision Project of the Twenty-Five Histories”. These important documents were revised with modern astronomical computational methods (Liu Ciyuan and Ma Liping, 2010).

It is special that there are solar positions in solar eclipse records. Such records in official historical are mainly found in those of the Western Han, Eastern Han, Tang and Song Dynasty. Our research (Ma Liping, 2008) found that the records of the Han Dynasties were computed according to uniform solar motion, while for those of the Tang Dynasty, an annual correction was added. The solar positions in these records were obviously calculated. Since the Eastern Han Dynasty, there are many invisible records of solar eclipse, sometimes even very high proportion (e.g., Northern Zhou). This is obviously not accurate calculation results, indicating that the existing conventional solar eclipse prediction system. Furthermore those records may be joined in the late historical compilation (Liu Ciyuan and Zhuang Weifeng, 1998). The solar and lunar eclipse records for the Sui, the Tang and the Five Dynasties are collected, examined and statistically analyzed (Liu Ciyuan and Ma Liping, 2013a). Those records in the Southern and Northern Dynasty are also analyzed (Liu Ciyuan and Ma Liping, 2013b). Ma Liping (2004a) compared those predictions with modern computation and found that their standard error of timing was 15 minutes before 1735 and 8 minutes from then on. Furthermore, more than 1100 extant local records of solar eclipse in the Qing Dynasty were examined and analyzed (Ma Liping, 2004b).

1.2 TABLE AND CANON OF SOLAR ECLIPSE

Tables of solar eclipses for the years B.C. 1500 to A.D.2050, occurred and will occur in 13 cities in China, had been presented by Zhang Peiyu (1990). *Chinese Historical Canon of Solar Eclipse* (Liu Ciyuan and Ma Liping, 2006) has included descriptions, in tables and charts, of all the visible solar eclipses that occurred and will occur in China for the 44 centuries, from 2300 BC to AD 2100. Tables of sunrise/sunset at 6 epochs, details for important visible Chinese eclipses in the next 50 years and the grand table for world solar eclipses for 45 centuries have been included in the appendices. The Canon is rich in contents and has equipped with many convenient and new methods for using it.

2 APPLICATIONS OF ANCIENT ECLIPSES RECORDS

Historical solar eclipse records play an important part in the study of chronology. Modern astronomers use them to study the Earth's rotation and secular acceleration. At the same time, ancient and modern records of solar eclipse provide useful information in the research of history of astronomy, such as the corresponding calendar accuracy, timing precision, astronomical observation system and the ancient philology.

2.1 APPLICATION TO HISTORICAL CHRONOLOGY

We have to say the Xia-Shang-Zhou Chronology Project. 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 of the late West Zhou Dynasty. The Xia-Shang-Zhou Chronology Project brought together scholars from literature, archaeology, astronomy, and radiocarbon dating in a bid to break the deadlock. After five years effort, the Project published its concise report (The Expert Group of Xia-Shang-Zhou Chronology Project, 2000). At its core is a chronological list, which includes approximate dates for the beginning of the Xia Dynasty (2070 BC) and early Shang Dynasty (1600 BC), and precise commencement dates for the reigns of some kings in the late Shang Dynasty (1300-1046BC) and every king in the West Zhou Dynasty (1046-771 BC). Among the 12 landmark fruits of the Project, 3 have something to do with ancient solar eclipse records (Liu Ciyuan, 2002a). The Double Dawn in the *Zhushu Jinian* (*Bamboo Chronicle*), "During the 1st year of King Yi (of the West Zhou Dynasty), the day dawned twice at Zheng", has been considered as a total solar eclipse at dawn. Thus Liu Ciyuan et al. (1999) obtained the first year of King Yi in the Western Zhou period, 899 BC, which is consistent with the literature, bronze and archaeological results. Firstly, Liu Ciyuan and Zhou Xiaolu (1999) had a comprehensive review on the previous works. Secondly, they developed a theory to express the sky brightness and human feeling when an eclipse takes place around sunrise. Then, they arranged a net work to observe the solar eclipse of 1997/3/9 and proved their theory. Finally, by searching all eclipses during BC1100-840(see fig.1), they identified the only equivalent, the eclipse of BC 899/4/21(Liu Ciyuan et al., 1999). The *Bamboo Chronicle* recorded: "In the 19th year of King Zhao, the sky turned very dark, pheasants and hares were shocked, (King Zhao) lost 6 divisions of the army by River Han. Through a wide discussion of astronomical parameters, this event can be identified with the total solar eclipse that took place on May 31, 976 BC (Liu Ciyuan,

2002b). The result of this paper is an independent support to the year of King Shao of “Xia-Shang-Zhou Chronology Project”.

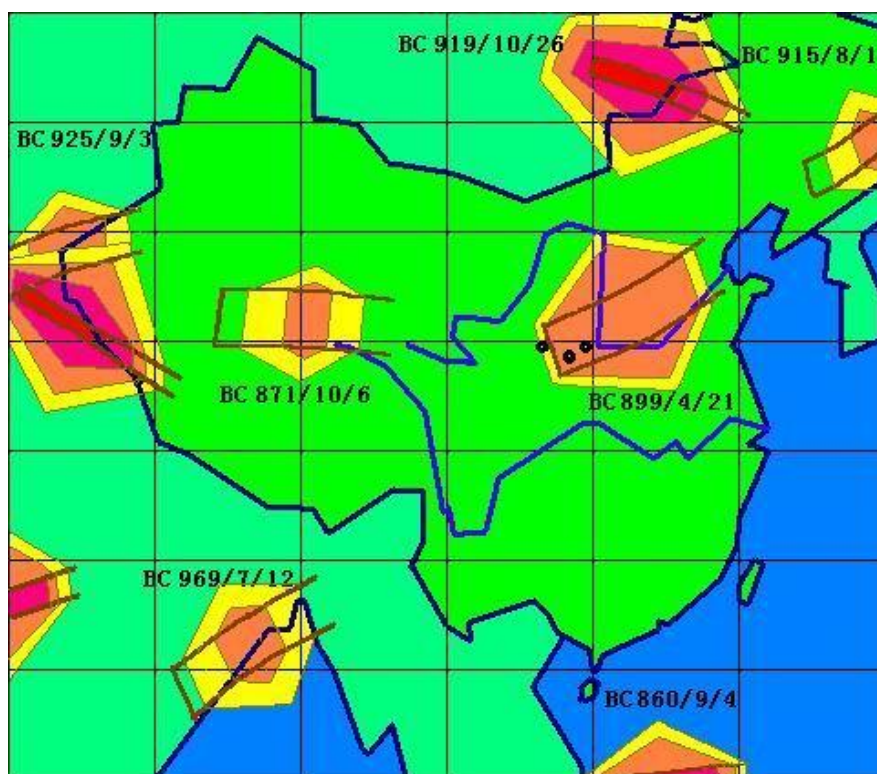


Fig. 4 Visible double dawn phenomena in China during 1000BC—840BC, taken from Liu Ciyuan et al., 1999.

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...” Most people thought that it relates to a solar eclipse. Wu Shouxian (1998, 2000) carried out a thorough analysis of these earlier investigations. Fourteen different conclusions contained in them were analyzed, and some apparent mistakes were found. The calculations made by these earlier researchers were also analyzed (Li Yong and Wu Shouxian, 1999). Finally, they 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 research group led by Li Xueqin (1999) re-evaluated the famous “three 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.

2.2 CONTRIBUTIONS TO THE SECULAR VARIATION OF THE EARTH'S ROTATION

Total solar eclipse records are very sensitive to the secular variation of the Earth's rotation. There are dozens of such records in ancient China. But due to the specific location is not very clear, average results can only be gotten from most of them (see Wu Shouxian and Liu Ciyuan, 1987). There are 18 terms of records which have clear dates and descriptions of total or nearly total solar eclipses in China before 300 A. D.

With the aid of these records, Liu Ciyuan(1985) compares and analyses the results on the research of secular acceleration of the Earth's rotation. Furthermore, Liu presented in works of Curott, Newton, Stephenson and Han Yanben with the result obtained by the author himself from eclipses canon of Watabe(渡边敏夫). It has been proved that the overwhelming majority of these records are reliable, but locations of these observations are void. We cannot ascertain that all observations were made in the capital. So as to make more precise analysis about secular acceleration of the Earth's rotation by these records, further textual research is necessary.

Zhang Peiyu and Han Yanben (1995) analyzed 34 timing solar eclipse observations recorded in The Twenty-Four Histories during the period from BC 2nd and to AD 8th century. Among them two solar eclipses were recorded twice respectively, and the date of another one is incorrect. Of all the 32 solar eclipse observations, 14 magnitudes of eclipse and 45 times of phase of eclipse are examined. The results are as follows: all times were recorded correctly except the only one, whose error is about one hour. According to these observations the authors probed into the tendency of the secular changes in the rotation of the Earth. The individual records may have the exact location and higher precision (see Han Yanben and Qiao Qiyuan, 2000). Better average value can be obtained from the timing solar eclipse records (see Li Zhisen and Yang Xihong, 1985). Even general records of solar eclipse, a huge number can also provide useful information (see Han Yanben et al., 1984).

2.3 APPLICATION OF SOLAR ECLIPSE RECORDS IN OTHER ASPECTS

Records of solar eclipse are also applied in some other ways. As we mentioned in subsection 1.1, Xing Gang and Shi Yunli (2005) used the records in checking the precision of the system of calendar astronomy in the Han Dynasty. Records of solar eclipse are also used to discuss the relationship among ritual, propagandism and eclipse predictions in the Qing Dynasty (Shi Yunli and Lü Lingfeng, 2002).

3 CONCLUSION

If we analyzed the early records of solar eclipse carefully, they can be used in chronology though the records are vague. Solar eclipse recorded in Chinese historical archives have been collected and studied. Although a significant amount of research has been done both in statistic of solar eclipse records and application of those records, there are many much work we can do, such as comparison of solar eclipse records between China and neighboring countries. Furthermore, some descriptions and records of solar eclipse in new archaeological discoveries need to be studied.

4 AKNOWLEDGEMENTS

I am grateful to National Astronomical Observatory of Japan, and to Dr Soma and Dr Tanikawa. I also wish to express my gratitude to Prof. Liu Ciyuan for helpful discussion in writing this paper.

5 REFERENCES

Note: in the following reference (C) indicates books, research paper written in Chinese. Most of these have English abstracts.

- Bo Shuren, 1980. Records of astronomical observations in the files of the Qing Tian Jian (the Royal Bureau of Astronomy) of the Qing Dynasty. *Ke-ji-shi Wen-jì (Collected papers in the history of science and technology, Science and Technology Press of Shanghai)*, iii: 155(C).
- Chen Jiujin, 1983. The conversion of the times of solar eclipse in ancient Chinese records with an analysis of their precision, 1983. *Studies in the History of Natural Sciences*, 1983, 2(4): 303-315(C).
- Chen Zungui, 1984. *A History of Chinese Astronomy*. Vol. 3. Shanghai: Shanghai 's Publishing House(C).
- China First Archives, Beijing Ancient Observatory, 1996. *Qingdai Tianwen Dangan Shiliao Huibian (A Collection of the Qing Dynasty Archival Materials of Astronomy)*, Zhengzhou: Elephant Press(C).
- Han Yanben, Li Zhisen, Lin Baisen, Yang Xihong, 1984. The parameter of variation in the rotational speed of the Earth from ancient central eclipse records of China. *ACTA Astrophysica Sinica*, 4(2):107-114(C).
- Han Yanben, Qiao Qiyuan, 2000. A ΔT with high precision derived from records of a total solar eclipse occurred in AD 1361. *Progress in Geophysics*, 15(1): 108-109(C).
- Li Xueqin, 1999. *Theses on Xia-Shang-Zhou Chronology*. Shenyang: Liaoning University Press(C).
- Li Yong, Wu Shouxian, 1999. Recovery of the ancient calculation of the Zhong Kang solar eclipse. *Studies in the History of Natural Sciences*, 18(3):234-240(C).
- Li Yong, Wu Shouxian, 2001. The Zhong-Kang solar eclipse recorded in “Shoushi Liyi”. *Journal of Nanjing University (Natural Sciences)*, 37(1): 17-22(C).
- Li Yong, Zhang Peiyu, Xu Bangxin, 1995. Research on 31 total(annual) solar eclipse records in Chinese ancient annals. *Journal of Nanjing University (Natural Sciences)*, 31(2): 227-236(C).
- Li Zhisen, Yang Xihong, 1985. The time records of the eclipses in ancient China and the long term variation of the Earth's rotation. *Science in China (Series A)*, 10(2): 163-170(C).
- Liu Ciyuan, 1985. Records of large solar eclipse in China before 300 A.D. *ACTA Astrophysica Sinica*, 5(4): 284-290(C).
- Liu Ciyuan, 2002a. Astronomy in the Xia-Shang-Zhou Chronology Project. *Journal of Astronomical History and Heritage*, 5(1): 1-8.
- Liu Ciyuan, 2002b. An ancient solar eclipse record “Tian-da-yi” in the 10th century BC. *Chinese Journal of Astronomy and Astrophysics*, 2(5): 391-395.
- Liu Ciyuan, 2005. The regular records of solar eclipse in ancient China and a computer readable table. *Archive for History of Exact Sciences*, 2005, 59(2):157-168.
- Liu Ciyuan, Li Jianke, Zhou Xiaolu, 1999. Study on “double dawn”. *Science in China(Series A)*, 42(11): 1224-1232.
- Liu Ciyuan, Liu Xueshun, Ma Liping, 2003. Examination of early Chinese records of solar eclipses. *Journal of Astronomical History and Heritage*, 6(1): 53-63.
- Liu Ciyuan, Ma Liping, 2006. *Chinese Historical Canon of Solar Eclipse*. Beijing: World Publishing Corporation(C).

- Liu Ciyuan, Ma Liping, 2008. An investigation on Zhu Wenxin's *An Examination on History Records of Solar Eclipse*. *Journal of Time and Frequency*, 31(1): 73-80(C).
- Liu Ciyuan, Ma Liping, 2010. Revision Project of the Twenty-Five Histories and general examination of all astronomical records. *The Chinese Journal for the History of Science and Technology*, 31(4): 501-508(C).
- Liu Ciyuan, Ma Liping, 2013a. The solar and lunar eclipse records in the Sui, Tang and the Five Dynasties. *Journal of Time and Frequency*, 36(2): 120-128(C).
- Liu Ciyuan, Ma Liping, 2013b. The solar and lunar eclipse records in the Southern and Northern Dynasties. *Journal of Northeast University (Natural Science Edition)*, 43(3): 510-516(C).
- Liu Ciyuan, Zhou Xiaolu, 1999. An examination into the ancient records on double dawn. *Studies in the History of Natural Sciences*, 18(1): 48-54(C).
- Liu Ciyuan, Zhuang Weifeng, 1998. Records on solar eclipse in the Ming Dynasty. *Studies in the History of Natural Sciences*, 17(1): 38-46(C).
- Lü Lingfeng, 2006. The eclipse records in historical documents of Qing Dynasty and the current research. *Journal of Guangxi University of Nationalities (Natural Science Edition)*, 12(1): 32-36(C).
- Lü Lingfeng, Shi Yunli, 2001. Accuracy of eclipse predictions and observations made during calendar-debating in the late Ming Dynasty, *China Historical Materials of Science and Technology*, 2001, 22(2): 128-138(C).
- Lü Lingfeng, Shi Yunli, 2003. Accuracy of solar eclipse predictions made in Qing Dynasty. *China Historical Materials of Science and Technology*, 2003, 24(4): 283-290(C).
- Ma Liping, 2004a. Official records of solar eclipse in Qing Dynasty. *Journal of Time and Frequency*, 27(2): 146-160(C).
- Ma Liping, 2004b. Local records of solar eclipse in the Qing Dynasty. *Studies in the History of Natural Sciences*, 23(2): 121-131(C).
- Ma Liping, 2008. Position of the Sun in ancient Chinese records of solar eclipse. *Studies in the History of Natural Sciences*, 27(1): 39-58(C).
- Von Oppolzer T R, 1962. *Canon of Eclipse*. Gingerich O translates. New York: Dover Publication.
- Shi Yunli, 2000. The eclipse observations made by Jesuit astronomers in China. *Journal for the History of Astronomy*, 31(2): 135-147.
- Shi Yunli, Lülingfeng, Zhang Binglun, 2000. A supplement to the collection of eclipse predictions preserved in the astronomical achieves in the Qing Dynasty. *China Historical Materials of Science and Technology*, 21(3): 270-281(C).
- Shi Yunli, Lü Lingfeng, 2002. A perspective into eclipse observations and records of the Qing Dynasty. *Journal of Dialectics of Nature*, 24(6): 44-50, 95(C).
- The Expert Group of Xia-Shang-Zhou Chronology Project, 2000. *The Concise Report of Xia-Shang-Zhou Chronology Project, 1996-2000*. Beijing: World Book Company(C).
- Wu Shouxian, 1998. A second look at the Zhong-Kang solar eclipse record. *Studies in the History of Natural Sciences*, 17(3): 250-253(C).
- Wu Shouxian, 2000. Research on determining the age of Zhong-kang solar eclipse in Xia Dynasty. *Studies in the History of Natural Sciences*, 19(2): 114-123(C).

- Wu Shouxian, Liu Ciyuan, 1987. The Progress on the research of the secular variation of the Earth's rotation by the ancient eclipses records. *Progress in Astronomy*, 5(2): 147-157(C).
- Xing Gang, Shi Yunli, 2005. On the solar eclipse records from the Han Dynasty and their application to the analysis of the precision of the system of calendar astronomy in the Han Dynasty. *The Chinese Journal for the History of Science and Technology*, 2005, 26(2):107-121(C).
- Zhang Peiyu, 1975. A study of records of the solar and lunar eclipses in scripts and on tortoise-shell or ox-bones. *ACTA Astronomica Sinica*, 1975, 16(2): 210-224(C).
- Zhang Peiyu, 1990. *Calendar Date and Astronomical Phenomena for Three Thousand Five Hundred Years*. Zhengzhou: Henan Education Press(C).
- Zhang Peiyu, Han Yanben, 1995. The timing solar eclipses records recorded in China and the secular changes in the Earth's rotation before the 8th century. *ACTA Astronomica Sinica*, 36(3): 314-320(C).
- Zhang Peiyu, Xu Zhentao, Lu yang, 1982. The ancient records of solar eclipses and a canon of solar eclipses for the years B.C. 1400 to B.C. 1100. *Journal of Nanjing University (Natural Sciences)*, (2): 371-409(C).
- Zhu Wenxin, 1934. *An Examination on History Records of Solar Eclipse*. Shanghai: The Commercial Press(C).
- Zhuang Weifeng, Wang Xinli, 1988. *General Collection of Ancient Chinese Astronomical Records*. Nanjing: Jiangsu Scientific & Technical Press(C).