Chin. J. Astron. Astrophys. Vol. 2 (2002), No. 5, 391–395
(*http://www.chjaa.org* or *http://chjaa.bao.ac.cn*)

Chinese Journal of Astronomy and Astrophysics

LETTERS

An Ancient Solar Eclipse Record "Tian-da-yi" in the 10th Century BC

Ci-Yuan Liu

Shaanxi Observatory, Chinese Academy of Sciences, Lintong 710600

Received 2002 June 13; accepted 2002 June 17

Abstract The ancient record "Tian-da-yi" (the sky darkened greatly) is identified with the solar eclipse on May 31, 976BC. This identification is demonstrated in this paper through a palaeographic, astronomical and chronological analysis. It is probably the earliest solar eclipse in Chinese history that can be so identified.

Key words: solar eclipses — history of astronomy

1 LITERATURE SOURCES AND PALAEOGRAPHIC STUDIES

The **Bamboo Chronicle** (Zhu Shu Ji Nian) is an ancient book that was written on bamboo in the 3rd century BC. It was unearthed in the 3$^{\rm rd}$ century and then was unfortunately lost. We can only find fragments of it in citations found in later books. The **Bamboo Chronicle** recorded: "In the 19$^{\rm th}$ year of King Zhao, "Tian-da-yi" (see Fig. 1 for the original Chinese writing), pheasants and hares were shocked, (King Zhao) lost the six armies at River Han". This event took place during King Zhao's expedition to the south Jingchu and is recorded also in **Chuxueji** (Vol. 7), **Kaiyuan Zhanjing** (Vol. 101), and in **Taiping Yulan** (Vol. 907). The story on King Zhao's expedition is also seen in Bronze inscriptions (He 1989). "Yi" is an ancient character, which is explained in the authoritative modern dictionary **Cihai** as "dark and shadowed". The **Erya**, a dictionary compiled before the common Era, says: "Yi, cloudy and windy". The **Shuowen**, a dictionary of the 1$^{\rm st}$ century, says: "Yi, the sky and the earth falling dark and shadow". "Tian-da-yi" consists of 3 Chinese characters: sky, great (or "very"), and "Yi". We can therefore translate "Tian-da-yi" as "The sky turned extraordinarily dark" or "the sky darkened greatly".

When a total or nearly total solar eclipse takes place, the sky darkens down rapidly; pheasants and hares flee in panic and a cold wind immediately blows because of uneven solar heating. These phenomena have been reported repeatedly in total solar eclipse observations. It is thus natural for us to associate "Tian-da-yi" with a total or nearly total solar eclipse. In the early period of the Zhou Dynasty, although people had already known solar eclipses, they could not predict them. If a large (factor) eclipse took place on a cloudy day, it would be most likely to be recorded as "Tian-da-yi". This situation is reminiscent of the "double dawn" event as identified

⋆ E-mail: liucy@ms.sxso.ac.cn

to have occurred in 899BC (Pang 1988; Liu 1999a, b). It also bears some resemblance with the record "eclipse and the sky darkened" in the history of Qin State in the 3^{rd} – 2^{nd} century BC (see **Shiji. Qinbenji** or **Shiji. Chronicle of the six states**).

Kaiyuan Zhanjing, an astrology encyclopedia compiled in the 8^{th} century, regards "Yi" and "Mai" (haze) as somewhat similar in meaning. Some examples (Vol. 101) are: "Tian-da-yi in Zhou in King Dixin's reign (1075–1046BC); in the 19^{th} year of King Zhao, Tian-da-yi, pheasants and hares were shocked; in the first year of King Huicheng (Wei State) the day darkened; the 16^{th} year four "Yi" in Handan (a place), many houses were damaged and people died". The first year of King Huicheng was 369BC, when an annular eclipse occurred in the capital of King Huicheng (factor 0.94). This same event was recorded as an eclipse in **Shiji. Chronicle of the six states**: "Solar eclipse in the 16^{th} year of Duke Xian (Qin State)". Here we can see, the same event recorded as "eclipse" at one place, but as "the day darkened" at another place. The first example, in King Dixin's reign, is difficult to identify because there is no exact year of the event. There were large eclipses (factors larger than 0.80) in 1070, 1067, 1063, 1062 and 1055BC at Zhou during this period. The last example (four Yi in Handan), however, may not correspond to an eclipse. It was probably a tornado.

Luo (1999) showed that the eclipse hypothesis for "Tian-da-yi" was reasonable from considerations of historic literature and palaeography. In fact, He (1989), Hirasei (1996) and Zhang (1998) had already suggested that this was an eclipse although further investigations were not made.

2 ANALYSIS BASED ON ASTRONOMICAL EVIDENCE

To identify this eclipse, we computed all solar eclipses occurring over the period 1000BC to 950BC. The capital of King Zhao was Zongzhou, presently known as Xi'an; Jingchu was an ancient state and its capital was today's Jiangling; the two cities are linked by the River Han. Four solar eclipses with large factors occurred in these areas: 980, 978, 976, and 969BC.

There is a great uncertainty attending the computation of eclipses 3000 years ago. This uncertainty is due mainly to long term changes in the Earth's rotation rate and the intimately related lunar tidal acceleration. For a long time, astronomers adopted the "Improved Lunar Ephemeris" to compute eclipses, in which the mean deceleration of Earth rotation was taken to be, c, 29.95 and lunar tidal acceleration was $\dot{n} = -22.44$. Most of historical eclipse canons and related commercial software packages have adopted these parameters (Zhang 1990; Mucke 1983). In recent years, significant progress has been in the measurement of both lunar tidal acceleration and earth's rotation, using new technology and ancient astronomical records.

Investigators of ancient records have tended to adopt the parameters $\dot{n} = -26$ and c=30 or 31 (Stephenson 1995; Pang 1999; Liu 1994; Zhang 1995). Slight changes in both c and $\dot{n}$ have much the same effect: the central eclipse belt moves in a west-east direction on the map. In fact, the earth's rotation is more complex and more uncertain, although the adopted values seem to have changed very little (29.95 to 30). That is to say, we are more confident with the measurement of lunar term, therefore we could reduce parameters (c=29.95, $\dot{n} = -22.44$) to parameters (c=33.5, $\dot{n} = -26$), which we call Para.1. We could easily discuss how changes in c affect our computed result of solar eclipses.

Now we chose Para.2: c=28, $\dot{n} = -26$, which is at the other side of our favored value (c=30 or 31). The two sets give a possible range for the practical situation. The two figures give the results: Fig. 1 for Para.1 (c=33.5) and Fig. 2 for Para.2 (c=28).

Table 1 gives the computed results for the four eclipses in Jingzhou and in Xi'an. Eclipse factor A stands for the maximum eclispe factor, which is independent of the geographical places and the parameter c. Factor B is for Jingzhou; factor C for Xi'an; factor 1 for Para.1; factor 2 for Para.2.

Table 1 Computed Circumstances of Solar Eclipses for Two Sets of Parameter Values

Date (BC)	Factor A and Type	Jingzhou (Factors)		Xi'an (Factors)	
		B1	B2	C1	C2
980–02–16	0.94 annular	0.70	0.87	0.57	0.74
978–12–17	1.01 total	0.70	0.70	0.82	0.08
976–05–31	1.04 total	0.77	**0.94**	0.62	0.80
969–07–12	0.93 annular	0.85	0.93	0.72	0.90

As the table and figures show, the three eclipses in 980, 976 and 969BC appear to have large factors in Jingzhou (0.87, 0.94 and 0.93, respectively). There is also one large factor eclipse (0.90) in Xi'an in 969BC. As to the one in 978BC, the eclipse factor was not large and the Sun was either close to the horizon (according to Para.1) or below the horizon (according to Para.2) at the time the maximum eclipse was at its maximum. In such a situation, the sky could not show a "darken and brighten" phenomenon (Liu 1999). Given the knowledge of the "double dawn" eclipse in 899BC (Liu 1999), we favour Para.2. Both astronomically and historically, the eclipse on 976BC.5.31 (B2) is the best choice to identify with the "Tian-da-yi" record.

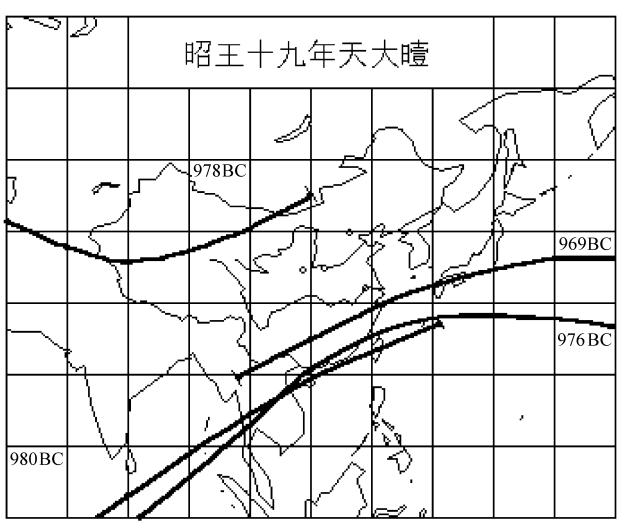

Fig. 1 Solar eclipse map with Para.1 ($c = 33.5$) during 1000–950BC.

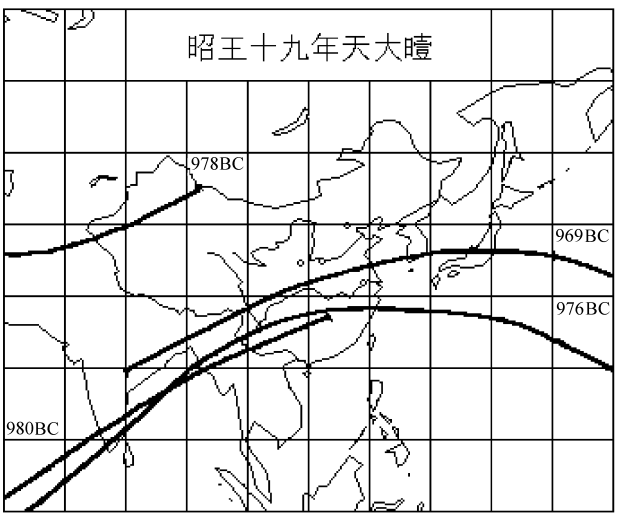

Fig. 2 Solar eclipse map with Para.2 ($c = 28$) during 1000–950BC.

3 DISCUSSION BASED ON CHRONOLOGICAL EVIDENCE

There is no exact and direct evidence as to the date of King Zhao. Recently, the Xia-Shang-Zhou Chronology Project (XSZ for short. see The Concise Report of Xia-Shang-Zhou Chronology Project, 1996–2000, World Book Company, 2000) has suggested the first year of King Mu (the successor king of King Zhao) to be 976BC (see Table 2). Logically, the 19$^{\text{th}}$ year (or the last year) of King Zhao should be 977BC. If we make a small adjustment to the original chronology list of the XSZ Project, and move the whole reign of King Zhao forward by one year, our identification of the eclipse in 976BC fits the chronology list of XSZ Project precisely. That is to say, the 19$^{\text{th}}$ year of King Zhao and the 1$^{\text{st}}$ year of King Mu need to be the same year. This adjustment does not conflict with any of the reasons whereby the Project has arrived at its conclusion.

Table 2 Original and Adjusted Chronology

King	—Original—		—Adjusted—	
	Reign (BC)	Total	Reign (BC)	Total
Kang	1020–996	25	1020–995	26
Zhao	995–977	19	994–976	19
Mu	976–922	55	976–922	55
Gong	922–900	23	922–900	23

Usually, a king began to count his reign year from the year following the accession. In Table 2 (original), King Zhao is such an example. However, at times a king started from the same year (Chen 2000) as shown by King Gong.

Xu (1999) identified this event with the eclipse on 978BC–12–17 for the reason that this day maybe the first day of the next year (according to the calendar used at that time, each year began with the New Moon just before the winter solstice). This identification does not require any adjustment to the chronology of XSZ. Li (1999) investigated the inscriptions on the **Bronze Jingfang**. The inscriptions recorded month, sexagenary day and lunar phase (without the year), and these fit the lunar phase of 977BC. On the other hand, the inscriptions mentioned some events that could be attributed to the last years of King Zhao. As a result, Li also prefers the eclipse in 978BC–12–17 (977BC, in the calendar at that time): the three took place in the same year (977BC, the 19^{th} year of King Zhao) solar eclipse, the date on the bronze with the lunar phase and the social events. As we have shown, the eclipse in 978BC is not a good fit from the astronomical point of view. In fact, we can include another explanation. If we date the **Bronze Jingfang** in the 18^{th} year, which is the year before the last year of King Zhao, everything would fit our adjusted chronology. The Bronze Jingfang still remains in 977BC (the 18^{th} year of Kin Zhao); the eclipse was in 976BC (the 19^{th} year, when King Zhao died and King Mu began to count his first year). Other words such as "eclipse in 976BC" also fits the Bronze Jingfang.

Therefore, the eclipse in 976BC is most likely to be the earliest solar eclipse that could be identified in Chinese history.

Acknowledgements Project supported by the National Natural Science Foundation of China (Grant No. 19973012). Acknowledgments to Dr. Ken Brewer and Dr. Jianke Li for their kind help with language improvement.

References

Chen Mei-dong, 2000, Studies in the History of Natural Sciences, 19, 234
He You-qi, Collection on Chronology of West Zhou, Hubei People's Pub., 1989, p.119
Li Xue-qin, Tian-da-yi and bronze Jingfang, informal papers from XSZ Project, 1999
Liu Ci-yuan, Zhou Xiao-lu, 1999a, Chin. Astro. Astrophys, 23, 249
Liu Ci-yuan, et al, 1999b, Science in China A, 42, 1224
Liu Ci-yuan, 1994, Pubs. Shaanxi Obs., 17, 77
Luo Kun, Literature investigation into "Tian-da-yi", informal paper of XSZ Project, 1999
Mucke H., Meeus J., Canon of Solar Eclipses –2003 to +2526, Astronomical Office, Vienna, 1983
Pang K. D. et al., 1988, Vistas in Astronomy, 31, 833
Pang K. D., et al., 1999, In: History of Oriental Astronomy, Holland: Kluwer
Stephenson F. R., Morrison L. V., 1995, Phil. Trans. R. Soc. Lond. A, 351, 165
Takarou Hirasei, Study in chronology of ancient China, Reports of Institute of Oriental Culture, Tokyo University, 1996
Xu Feng-xian, Tian-da-yi, informal papers from XSZ Project, 1999
Zhang Pei-yu, 1990, Calendar and Astronomical Phenomena in 3500 years, Henan Education Press
Zhang Pei-yu, Han Yan-ben, 1995, Acta Astro. Sinica, 36, 314
Zhang Wen-yu, 1998, In: Studies of Chronology from West Zhou, Guizhou People's Pub., p.370