A NEW ATTEMPT TO DATE THE XIA, SHANG AND WESTERN ZHOU DYNASTIES BY SOLAR ECLIPSES

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Abstract

The identification of six significant solar eclipses during specific years of the reigns of ancient Chinese kings from the Xia, Shang and Western Zhou Dynasties has made it possible to establish an absolute chronology back to the first year of King Yu, 2070 BC.

Keywords: Solar eclipses, Earth's rotation, Lunar Secular Acceleration, ancient Chinese Dynasties, ancient Chinese chronology.

Introduction

No original documents exist from the earliest dynasty, Xia, circa 2000 BC, but much later chronicles mention important solar eclipses during the reigns of the first kings of this dynasty. The earliest historical texts that contain systematic records of solar eclipses are the *Spring and Autumn Annals* (770-476 BC). Before that period, during the Xia, Shang and Western Zhou Dynasties, the solar eclipse records are vague and sporadic. Even if a text is well preserved and correctly translated, there may be no precise information about where the eclipse took place or in which month and day. An important method for eliminating false solutions is to find a reference to the day in the *ganzhi* 60-day cycle, which is known to have been used uninterruptedly since at least the 13th century BC.

The lengths of the reigns of Chinese rulers prior to 841 BC are still uncertain and during the 20th century several attempts were made to identify ancient eclipse records in order to date the earliest dynasties, for instance Kevin D. Pang (1987). In 1986, F. R. Stephenson and M. A. Houlden published the *Atlas of historical eclipse maps, East Asia 1550 B.C.-A.D. 1900* in order to finally solve the problems concerning the dating of the Chinese solar eclipses. Unfortunately this extensive publication was not a major step forward and, when it proved that not one of the oldest solar eclipse records could be identified, Stephenson came to the conclusion that the ancient Chinese texts were more or less useless. On the other hand, one cannot expect that Stephenson's method is sufficiently accurate for these early epochs because it consists mainly of extrapolations based on a value for the sidereal lunar secular acceleration, -26 ±2 arc seconds/century^2, determined from an analysis of the transits of Mercury 1677-1973 (Morrison and Ward 1975). In the same solution, the excess motion of the perihelion of Mercury was found to be +41.9 ±0.5 arc seconds/century, which deviates by 1.13 arc seconds/century from the prediction by Einstein's general theory of relativity, confirmed by other investigations.

Later an official Chinese group of archaeologists, astronomers, and historians started the Xia-Shang-Zhou Chronology Project (2000) to establish a historical reference frame. Astronomers lead by Ciyuan Liu, National Time Service Center at the Chinese Academy of Sciences, made new calculations with different values for the braking of the Earth's rotation (Liu, Liu and Ma 2003). With this method it was possible to make several new identifications, but it was mostly impossible to find a unique solution.

The author's method and earlier results

In 1985 I started to test my computer program by making comparisons with the Chinese solar eclipse records, but I soon realised that it was not possible to both determine one's own computation parameters and to identify the unknown dates for solar eclipses over such a wide area. The only Chinese solar eclipse record that gave a convincing solution was the so-called "double dawn" eclipse in Zheng, during the Zhou Dynasty, which could be dated to 899 BC. This result was presented in 1996 at the Oxford V Symposium in Santa Fe, Henriksson (2005). After the successful identification of the two total solar eclipse records in Babylon separated by 301/300 years with the total solar eclipses in 1859 BC and 1558 BC, it was possible to date the Old Babylonian Kingdom, the Old Assyrian Kingdom, the Old Hittite Kingdom and the 13th-20th dynasties in

Egypt, as presented in papers at the SEAC 2002 Conference in Tartu, Henriksson (2006) and at the SEAC 2004 Conference in Kecskemet, Henriksson (2007).

In my computer program I have always used Carl Schoch's values for the sidereal lunar secular acceleration, -29.68 arc seconds/century^2, and for the braking of the rotation of the earth, 36.28 seconds/century^2 (Schoch 1931). He calibrated the apparent acceleration of the moon from a very accurate direct observation, by Timocharis, of an occultation of Spica by the moon in 283 BC, visible in Alexandria, which gives a 2200-year-long time basis. This is more than 7 times longer than the 300-year interval primarily used to calibrate the corresponding parameters in the eclipse calculations by Stephenson *et al.* since 1984.

In the paper by Liu *et al.* (2003) there is a critical discussion of the different interpretations of the ancient texts that mention possible solar eclipses. When I compare my result with the historically possible alternative solutions for the ancient Chinese solar eclipses, suggested by Liu and his group, there is always one solution in common. All my dates are given in the Gregorian Calendar.

Eclipses during the Xia Dynasty

Three Miao eclipses. According to tradition, Emperor Yao had big problems with the flooding of the large Rivers and the skilful Gun was ordered to solve these problems. However, after nine years the situation had not improved, the emperor lost patience, and Gun was sentenced to death. Yu, the son of Gun, was promoted to fulfil his father's work and he was very successful and became a great hero.

After that there was great disorder among the Three Miao tribes who probably occupied a large area in the Yangtze River valley and south of the Huai River. There is a reference to eclipses related to the rebellion of these people in the "Against Aggressive Warfare" chapter of the *Mozi*, which 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 for three mornings. A dragon appeared in the temple. Dogs cried in the markets. In the summer there were floods, and the 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 upheld the auspicious command from the heaven to attack the Miao."

These bad omens are also mentioned in other texts and, according to them, this event occurred before the great Yu founded the Xia Dynasty. Pang and Yau (1996) have proposed that both "... the Sun rose at night" and "...the demoniac Sun rose at night" refer to the phenomenon of a double dusk or a double dawn.

From a combination of all available historical sources, the Xia-Shang-Zhou Chronology Project (2000) has chosen 2070 BC as the starting year of the Xia Dynasty (i.e. the year when Yu ascended the throne). Liu *et al.* (2003) found six possible double dusk eclipses and five possible double dawn eclipses between 2250 BC and 1850 BC using a fixed value, -26.0 arc seconds/century^2, for the lunar secular acceleration, but allowing the parameter *c*, the braking of the earth's rotation, to vary. With $c = 30 - 33$ seconds/century^2, a total eclipse took place in the region of the Three Miao at sunset on April 29, 2072 BC, which is in very good agreement with the date from the Xia-Shang-Zhou Chronology Project. However, this method is *in principle not correct* because the energy to accelerate the moon is taken from the deceleration of the rotation of the Earth. Every value for the secular acceleration of the moon corresponds to a unique value for the braking of the rotation of the Earth. (The sum of the angular momentum is constant.)

According to my calculations there were in fact three cases of "rising of the sun during the night" eclipses within four years at the time when Yu got the auspicious command from heaven to attack the Three Miao. The text also mentions that it rained blood on three mornings. The people living in the valley of the Xia-dominated Yellow River considered the Three Miao people living in the Yangtze River valley as uncivilised barbarians with a strange religion. The disorder in the heavens, mainly above the Three Miao territory, was a sign for Yu to punish them:

2075 BC, June 11: Annular solar eclipse before sunset in the eastern part of the area occupied by the Three Miao, and central in the Xia capital Luoyang, with magnitude 0.960.

2072 BC, April 11: Total solar eclipse before sunset completely covering the western area of the Three Miao.

2071 BC, March 31: Total solar eclipse at sunrise to the east of the Three Miao area, but the magnitude was still very great in the south-eastern part of their area.

These dramatic solar eclipses served later as a historical benchmark for the beginning of the Xia-Dynasty in 2070 BC, see Fig. 1.

Zhongkang eclipse. Zhongkang was the fourth King of the Xia Dynasty. From his fifth year there is the following passage in the "The Punitive Expedition of Yin" chapter of the *Book of Documents* that may be re-

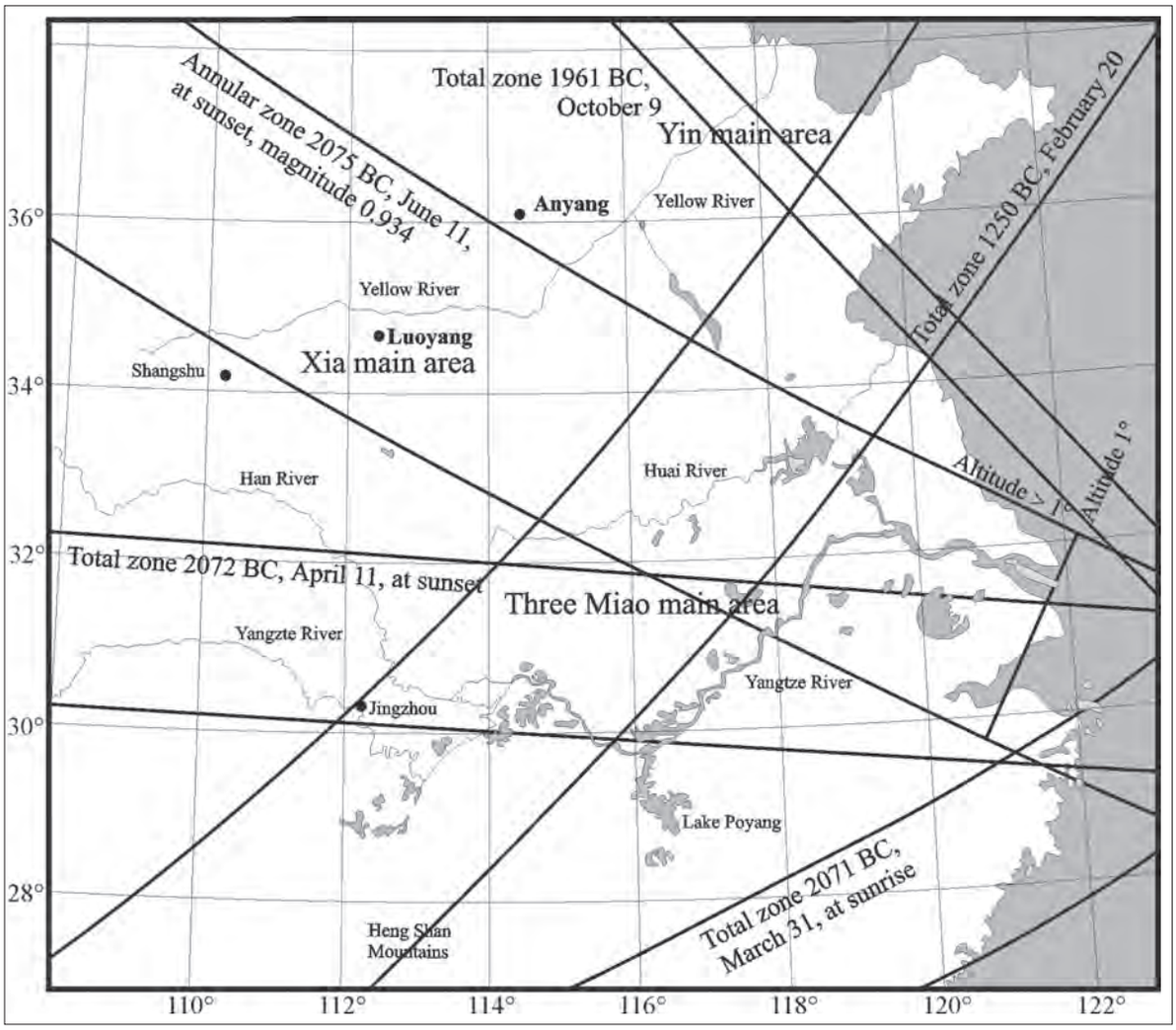

Fig. 1. Map of Central China with zones of total and annular eclipses.

garded 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 impersonators 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 1893, p.165-166).

The prince of Yin was ordered to punish the astronomers He and Ho. The reason may have been that the eclipse was total in Yin and not in the Xia capital Luoyang. In the Xia-Shang-Zhou Chronology Project, Wu Shouxian (2000) proposes 2043, 2019, 1970 and 1961 BC as possible dates for this event.

According to my calculations this fits perfectly with the solar eclipse in 1961 BC, on October 9, which was total in the Yin territory in the eastern part of the Yellow River valley, but only had magnitude 0.865 in Luoyang, see Fig. 1. The central star in the Chinese constellation *Fang* was π Sco and the sun was close to this star in 1961 BC, on September 29. This means that the solar eclipse took place 10 days after the passage of the central star of the constellation Fang.

Western Zhou Dynasty

It is written in the Old Version of the *Bamboo Annals* that "During the first year of King Yi the day dawned twice at Zheng." Yi was a King of Western Zhou and the first year of his reign has been dated to between 966 BC and 899 BC by different authors. K. Pang (1987) analyzed this eclipse and dated it correctly to 899 BC, but his calculation of the brightness of the morning sky was not performed correctly.

At the Oxford V Conference in Santa Fe 1996 I presented my own calculations of the brightness of the morning sky for the annular solar eclipse on April 11,

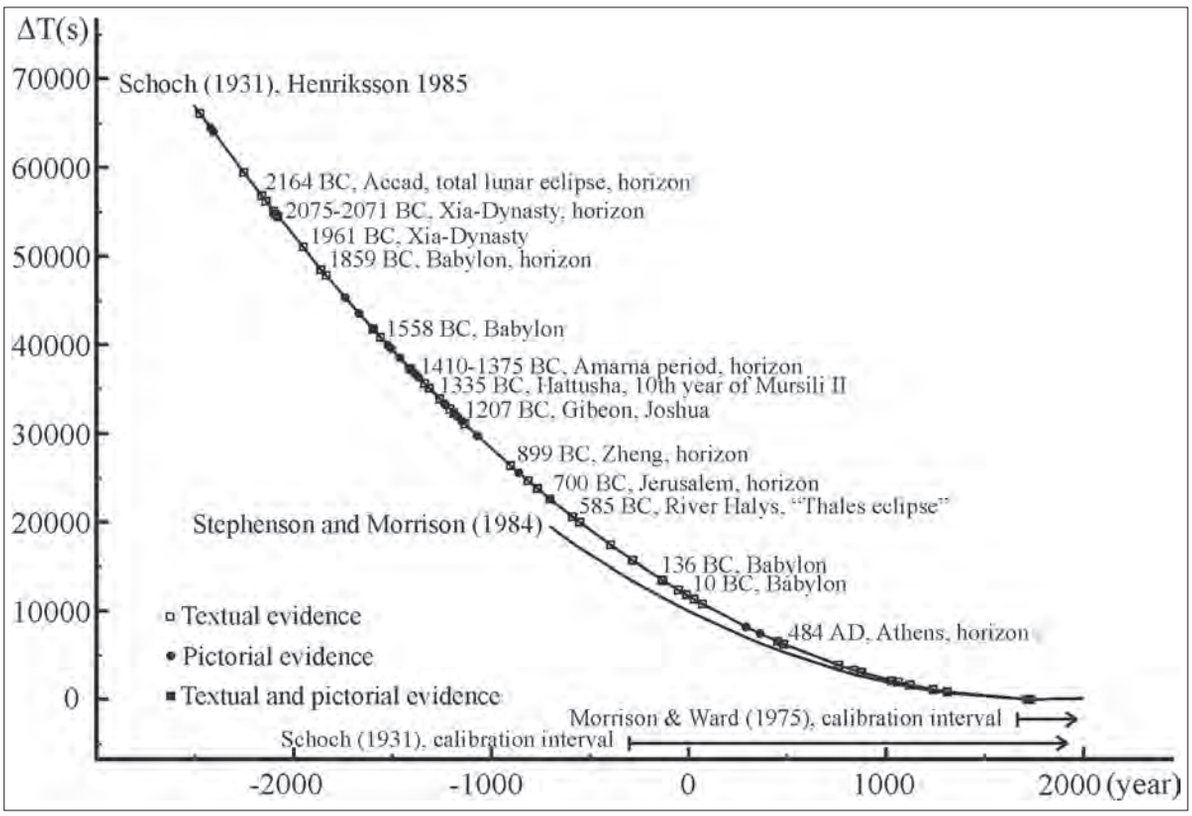

Fig. 2. The parabolic time-shift, ΔT, due to the tidal deceleration of the rotation of the Earth as a function of time with the coefficient 36.28 from Schoch (1931) and 31.0 from Stephenson and Morrison (1984). The unit for the coefficients is seconds/(century)^2 and the time is reckoned from 1800.0. The symbols correspond to identified solar eclipses, mostly total or annular. Most of the identified eclipses can be found in Henriksson (2005, 2006 and 2007).

899 BC, at 04.49 local mean solar time, ending 2 minutes before sunrise (Henriksson 2005).

A similar correct result is also independently presented by Liu, Liu and Ma (2003).

Discussion of Methods Used to Calculate Solar Eclipses

Almost all modern computer programs for the calculation of ancient solar eclipses are based on the theory by Stephenson and Morrison (1984) with tables for ΔT = (the time on the uniform time-scale Terrestrial Time (TT)) – (the Earth's rotational time-scale Universal Time (UT)). Before the introduction of atomic clocks in 1955 the Terrestrial Time must be calculated indirectly from old telescopic observations expressed in Universal Time (Martin 1969). There is no way to avoid circular arguments and the interval is so short that non-tidal effects are incorporated in the parabolic fit of ΔT, Fig. 2. Stephenson *et al*. extrapolate back to the ancient eclipses via low quality lunar eclipses. Great deviations are interpreted as unknown non-tidal effects (Morrison and Stephenson 2002). All time-dependent parameters in the theory by Schoch are expressed in UT. He used the best-defined ancient solar eclipses in his calibration, including Thales' eclipse in 585 BC and observations by Hipparchos. None of the solar eclipses plotted in Fig. 2 can be calculated correctly by Stephenson and his followers, not even the late solar eclipse in Athens in 484 AD, and they are working hard to explain why. I have removed non-tidal effects from Schoch's sidereal lunar secular acceleration and determined an improved value, -29.65 arc seconds/century^2.

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NAUJAS BANDYMAS DATUOTI SIA, ŠANG IR VAKARŲ DŽOU DINASTIJAS PAGAL SAULĖS UŽTEMIMŲ DUOMENIS

Göran Henriksson

Santrauka

Nėra išlikusių originalių dokumentų apie ankstyvąsias Sia dinastijas, valdžiusias apie 2000 m. pr. m. e., bet daug vėlesnėse kronikose minimi svarbūs saulės užtemimai pirmųjų valdovų valdymo laikotarpiu. XX a. keletą kartų buvo bandyta rasti senovinių įrašų apie saulės užtemimus, siekiant datuoti ankstyvąsias dinastijas (žr., pvz., Pang 1987). Oficiali Kinijos archeologų, astronomų ir istorikų grupė 2000 m. pradėjo Sia-Šang-Džou chronologinį projektą (Xia-Shang-Zhou 2000), siekdami nustatyti istorinių įvykių seką. Ciyuan Liu vadovaujami astronomai atliko naujus skaičiavimus, atsižvelgdami į Žemės sukimosi netolygumo reikšmes (Liu, Liu and Ma, 2003).

Sugretinus visus turimus istorinius šaltinius Sia-Šang-Džou chronologinis projektas (2000) Sia dinastijos pradžią nustatė 2070 m. pr. m. e. Prieš didžiajam Ju įkuriant Sia dinastiją, tekstuose buvo minimi bloga pranašaujantys ženklai, kaip antai, „demoniškoji Saulė patekėjo naktį". Tai galėjo reikšti vadinamąjį dvigubų sutemų ar dvigubos aušros fenomeną, susijusį su saulės užtemimu saulėtekio arba saulėlydžio metu. Mūsų skaičiavimais, trys vadinamieji „saulės patekėjimai naktį" galėję būti ketverių metų laikotarpiu įvykę trys saulės užtemimai tuo laiku, kai Ju sulaukė palankaus ženklo iš dangaus pulti San Miao („trejų Miao") gentį. Svarbiausias iš tų saulės užtemimų įvyko 2072 m. pr. m. e. balandžio 11 d. ir buvo matomas kaip visiškas saulės užtemimas visoje pagrindinėje San Miao teritorijoje. Penktaisiais ketvirtojo Sia valdovo Džongkango metais yra nuoroda į saulės užtemimą, kuris tiksliai sutampa su visišku saulės užtemimu 1961 m. pr. m. e. spalio 9 dieną.

Senojoje „Bambuko metraščių" versijoje taip pat rašoma, kad „pirmaisiais valdovo I valdymo metais Dženge diena išaušo du kartus". I buvo vakarų Džou valdovas, ir šį reiškinį galima aiškinti žiediniu saulės užtemimu prieš pat saulėtekį 899 m. pr. m. e. balandžio 11 d., pirmą kartą identifikuotą Pang Sunjoo (1977).

Vertė Jonas Marozas, Jonas Vaiškūnas