

Reliability of Eclipse Records in Japanese Ancient Periods

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Abstract: Eclipse records began in the 7th century in Japan. Eclipses in the 7th century were recorded in the *Nihongi* and their reliability changed according to the volumes. Eclipses in the 8th century were recorded in the *Shoku-Nihongi* but most of them were written according to the predictions at the time. Eclipses between the 9th and 11th centuries were recorded in various literatures and diaries but it is not easy to decide whether they were based on actual observations or not.

Keywords: Earth's Rotation, Eclipses, Ancient Records

1. INTRODUCTION

Ancient total or annular solar eclipse observations provide the values of $\Delta T = TT - UT$, where TT is Terrestrial Time, which is a uniform measure of time, and UT is Universal Time, which is determined by the rotation of the Earth. Hence we can investigate how the past Earth's rotation speed varied with time from such observations (see Stephenson 1997, Tanikawa & Sôma 2004, Sôma et al. 2004, Tanikawa et al. 2010). However there are many eclipse records based on predictions at the time and it is not always evident if the records were based on actual observations or not. Therefore for our investigations of the past Earth's rotation speed we need to distinguish the actual eclipse records from predicted ones.

In this paper we report the results of our investigations about the reliability of Japanese eclipse records until the 11th century. The dates are given here in the Gregorian Calendar although the actually recorded dates in those days in Japan were in luni-solar calendars.

2. ECLIPSE RECORDS IN THE NIHONGI

Ancient Japanese astronomical records of aurorae, eclipses, comets, meteors, occultations and appulses of planets were given in *Rikkokushi* (六国史, *Six Formal Japanese History Books*, see Table 1). The Japanese astronomical records began in AD 620 in the *Nihongi* (*Chronicle of Japan*) and the first eclipse record was that of the total solar eclipse in AD 628. In total there are 11 solar eclipses and 2 lunar eclipses in the *Nihongi*.

Table 1. 六国史 Six Formal Japanese History Books

Name of the Book	Period	Completed
日本紀(日本書紀) <i>Nihongi</i>	— 697	720
続日本紀 <i>Shoku-Nihongi</i>	697 — 791	797
日本後紀 <i>Nihon-Kôki</i>	792 — 833	840
続日本後紀 <i>Shoku-Nihon-Kôki</i>	833 — 850	869
日本文徳天皇実録 <i>Nihon-Montoku-Tennô-Jitsuroku</i>	850 — 858	879
日本三代実録 <i>Nihon-Sandai-Jitsuroku</i>	858 — 887	901

The *Nihongi* was written in Chinese characters and the volumes of the *Nihongi* were classified into the α group and the β group according to the usage of Chinese characters (Mori 1991, 1999). The volumes in the α group were written using correct Chinese characters whereas those in the β group had improper Chinese characters. This implies that the volumes in the α group were written by people from China and those in the β group were written by Japanese scholars. The periods of the α and β groups and the names of the emperors or empresses of the periods in the 7th century are given in Table 2. Tanikawa & Sôma (2008) and Sôma & Tanikawa (2011) showed that astronomical records in the β group are reliable whereas those in the α group are not reliable. For example the total solar eclipse on 628 April 10 and the lunar occultation of Mars on 681 November 3 are recorded in the β group of the *Nihongi* and they were actually occurred (for their reliability see Sôma et al. 2004), but a lunar occultation of a star on 642 August 9 and a lunar eclipse on 643 June 8 recorded in the α group of the *Nihongi*

should not have been actually seen in Japan. A lunar occultation of the first magnitude star Aldebaran on 640 March 3 is recorded in the β group of the *Nihongi* and it is also shown that it was the real event although it was only 2-3 years before the false records in 642-643. All the astronomical records in the *Nihongi* including eclipses are given in the paper by Tanikawa & Sôma (2008).

Table 2. The α and β groups of *Nihongi* for the period after AD 593

Group	AD Years	Emperor
β	593–628	Suiko 推古*
	629–641	Jomei 舒明
α	642–645	Kôgyoku 皇極*
	645–654	Kôtoku 孝徳
	655–661	Saimei 斉明*
	661–671	Tenji 天智
β	672–686	Tenmu 天武
—	686–697	Jitô 持統

* These were empresses. Kôgyoku and Saimei were the same empress with different names.

It should be noted that the volume of the Jitô era of the *Nihongi* could not be classified into either α or β . There are 6 records of solar eclipses in only 6 years 691–696 in the Jitô era of the *Nihongi* but most of them are unobservable in Japan and therefore the eclipse records in the Jitô era of the *Nihongi* are not reliable.

2 ECLIPSE RECORDS IN THE SHOKU-NIHONGI

The *Shoku-Nihongi* (続日本紀) is the second Formal Japanese History Book, which describes events between 697 and 791. There are many records of solar eclipses in the *Shoku-Nihongi* and the first 10 dates of those eclipses are: 698 Aug 12, 698 Dec 8, 699 Nov 27, 701 May 12, 702 Sept 26, 704 Mar 10, 706 July 14, 707 Jan 8, 707 Dec 29, and 708 Dec 17, but only 3 of them were observable in Japan (the solar eclipse on 702 Sept 26 was near total in Kyushu; the solar eclipse on 707 Dec 29 was partial in the western Japan; the solar eclipse on 708 Dec 17 was a shallow partial eclipse in the eastern Japan) and other 7 events were not observable in Japan. Especially the solar eclipse on 698 Aug 12 was not observable anywhere in the World. In addition to them there should have been a total solar eclipse in the north-eastern Japan on 700 May 23, and there should have been a partial solar eclipse in Kyushu on 703 Mar 22, but neither of them are given in the *Shoku-Nihongi*. Therefore it is concluded that the eclipse records in the *Shoku-Nihongi* are not reliable.

Other astronomical records in the *Shoku-Nihongi* include the following:

A conjunction of the Moon with a star at night of 723 Dec 28 (the star should be Venus and the actually this event was seen in the morning sky).

A conjunction of the Moon with Mars on 724 May 15 (actually the conjunction occurred 2 days later).

A conjunction of the Moon with Saturn at night on 725 Feb 20 (actually the conjunction occurred 6 days later).

As noted in the parentheses it is doubtful that these statements were based on actual observations. In summary astronomical records given in the *Shoku-Nihongi* are not reliable.

3 OTHER JAPANESE ECLIPSE RECORDS BETWEEN THE 9TH AND THE 11TH CENTURIES

Other eclipse records have not been systematically investigated yet. Here only a few cases are noted.

A record for the solar eclipse on 873 July 28 is given in the *Nihon-Sandai-Jitsuroku* (日本三代実録), which is the last of the Six Formal Japanese History Books. The record says, “秋七月癸亥朔，日蝕無光，虧昃如月初生，自午至未乃復” which means “In Autumn on the first day of the 7th month there was a solar eclipse, and there was no light. The eclipsed sun was like a new-born moon in the west. The eclipse began in the 午 (Uma in Japanese, Wu in Chinese) hour (11–13h) and ended in the 未 (Hitsuji in Japanese, Wei in Chinese) hour (13–15h).” Almost all of the eclipses recorded in this era were predicted ones and the records usually said “the sun was eclipsed” only, but this record has detailed descriptions, which suggest that the record was written from an actual observation. We know that the

eclipse was seen as an annular eclipse somewhere in or near Japan and the article suggests that the eclipse was annular in Kyoto. The same eclipse was also recorded in Nishapur, Iran, and the record also suggested that the eclipse was annular in Nishapur. The reliability of these eclipse records were discussed by Tanikawa & Sōma (2004).

For the solar eclipse on 878 October 29 the *Nihon-Sandai-Jitsuroku* says, “the maximum of the eclipse was at “戌 4 刻 1 分” and the magnitude was 13 半強/15”. The character 戌 means the time 19–21h. The 2-hour interval was divided into 刻 (koku in Japanese, ke in Chinese) and 分 (bu or hun in Japanese, fen in Chinese). There were several systems in which each 2-hour interval had different numbers of 刻 and 分 and we are not sure what system was used in the description in the above record. 半強 means more than a half. As shown in Fig. 1 the solar eclipse on 878 October 29 should not have been seen in Japan and therefore it is apparent that this record was not based on actual observations but was based on some prediction. The calendar system used in Japan at that time was Senmyō-reki (宣明曆, Xuanming-li in Chinese). How to calculate Senmyō-reki was written by Ando (1663, 1676). If one calculates the 878 October 29 solar eclipse by Senmyō-reki, the maximum of the eclipse is obtained to be at the time 戌 8 刻 16 分, and the maximum magnitude is 12 半強/15. In the case of Senmyō-reki the 2-hour interval consists of 8 刻 28 分 and 刻 consists of 84 分 and therefore 1 day is equal to 100 刻. The differences between the record and Senmyō-reki’s prediction in the times (戌 4 刻 1 分 vs 戌 8 刻 16 分) and magnitudes (13 半強 vs 12 半強 out of 15) suggest that the prediction was made by other methods or they made mistakes in calculating the prediction. The difference in the times of the maximum eclipse might be due to different systems of the division of the 2-hour intervals.

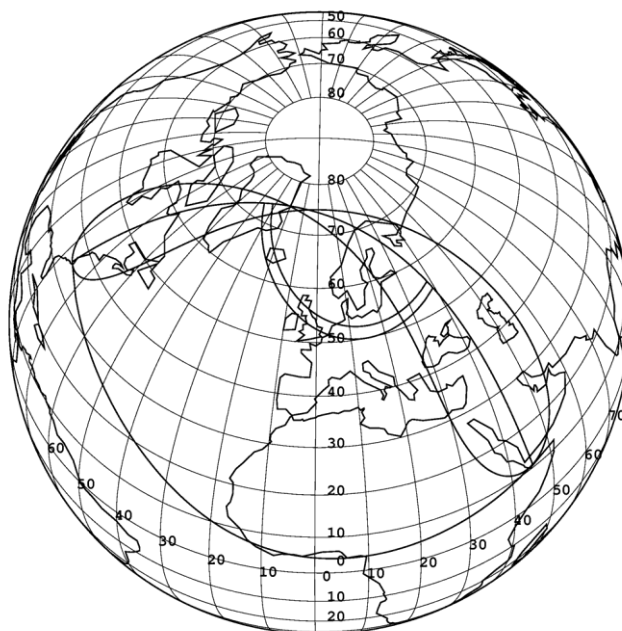


Figure 1: Eclipse map for the solar eclipse on 878 Oct 29. This figure shows the visible area of the solar eclipse. This is drawn using the parameter value $TT - UT = 3400s$.

Chōya-Gunsai (朝野群載) is a collection of literary works during the late Heian Period (平安時代). It was compiled by Miyosi no Tameyasu (三善為康; born in 1049 and died in 1139), who was an aristocrat at that time, and it was completed in 1116. It has a record of the solar eclipse on 975 Aug 10. It says, “the beginning of the eclipse was at the time ‘卯 1 刻 3 分’, the maximum at ‘辰 2 刻 1 分’, and the end at ‘巳 0 刻 2 分’. The maximum magnitude of the eclipse was 4/15.” The characters 卯, 辰, and 巳 mean the times 5–7h, 7–9h, and 9–11h, respectively. *Nihon-Kiryaku* (日本紀略) is a history book written in the late Heian Era. The editor and the completion year of *Nihon-Kiryaku* are not known but it serves as a supplementary collection to the *Six Formal Japanese History Books*. *Nihon-Kiryaku* says, “There was a solar eclipse. Someone said that the magnitude was 11/15 but some other person said that the Sun was totally eclipsed at 卯 or 辰 (which means 5-9h), there was inky blackness, and no light, birds hurled, and stars were seen.” From the concrete descriptions it is highly probably that this was total in Kyoto and our calculations show that it was actually total in Kyoto (Tanikawa & Sōma, 2004). Note that this eclipse can be calculated by Senmyō-reki as follows: the eclipse begins at 卯 5 刻 12 分, maximum at 辰 2 刻 23 分, end at 辰 7 刻 62 分, magnitude 9 半強/15.

Shōyuki (小右記) is a diary written by Fujiwara no Sanesuke (藤原実資; born in 957 and died in 1046) who became an official in the mid-Heian period. It has a record of the lunar eclipse on 1031 Aug 5. It says, “There was a total lunar eclipse. The beginning of the eclipse was at the time ‘酉 7 刻 50 分’, the maximum at ‘亥 0 刻 32 分’, and the end at ‘子 1 刻 42 分’.” The characters 酉, 亥, and 子 mean the times 17–19h, 21–23h, and 23–1h, respectively. The actual eclipse times at Kyoto should have been a few hours later, but the recorded times are exactly the same as those calculated by Senmyō-reki. Therefore we can see that the time system Fujiwara no Sanesuke used for this eclipse record was followed by the rule that the 2-hour interval consists of 8 刻 28 分 and 刻 consists of 84 分.

4 CONCLUSION

Finding actual eclipse records in ancient times are important to determine the Earth's rotation rate in the past. Many eclipses were recorded in ancient times in the world, but they were not always based on actual observations and it is not always clear if they were based on actual observations. Therefore it is important to find eclipse records based on actual observations.

Eclipse records began in the 7th century in Japan. The reliabilities of eclipse records between 7th and 11th centuries were discussed in this paper. Eclipses in the 7th century were recorded in the *Nihongi* and their reliability changed according to the volumes, namely the records in the volumes in the β group were based on actual observations whereas those in the α group were based on predictions at the time. Eclipses in the 8th century were recorded in the *Shoku-Nihongi* but most of them were written according to the predictions at the time. Eclipses between the 9th and 11th centuries were recorded in various literatures and diaries but it is not easy to decide whether they were based on actual observations or not.

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