

EARTH'S ROTATION IN THE 7TH CENTURY DERIVED FROM ECLIPSE RECORDS IN JAPAN AND IN CHINA

M. SÔMA¹⁾, K. TANIKAWA¹⁾, and K.-A. KAWABATA²⁾

¹⁾ National Astronomical Observatory of Japan
Mitaka, Tokyo 181-8588, Japan
e-mail: somamt@cc.nao.ac.jp, tanikawa.ky@nao.ac.jp

²⁾ Emeritus Professor of Nagoya University
Hanakoganei 4-39-15, Kodaira, Tokyo 187-0002, Japan
e-mail: kawabata-nagoya@jcom.home.ne.jp

ABSTRACT. It is generally accepted that the solar eclipse of AD 628 recorded as total in the Nihongi (Annals of Japan) was in fact a partial one. We compare the solar eclipses of AD 628 and AD 637 and the lunar occultation of Mars of AD 681 recorded in Japan and the solar eclipses of AD 616 and AD 702 recorded in China, and show that the eclipse of AD 628 could be indeed total, and we derive the Earth's rotation in the 7th century from these records.

1. INTRODUCTION

The solar eclipse of 628 April 10 was recorded as “The sun was totally eclipsed” in the Nihongi (The Nihongi is also known as the Nihon-Shoki; “Nihon” means Japan and “gi” or “Shoki” means Annals). This event is the first solar eclipse recorded in the Nihongi, and this is the only solar eclipse recorded as total in the Nihongi. Nine years later, on 637 April 1, there was another solar eclipse observed in Japan. It was also recorded in the Nihongi, but only recorded as “The sun was eclipsed”. It is assumed that these records were based on the observations made at Asuka where the capital was located at that time (approximate longitude $135^{\circ} 50'E$, latitude $34^{\circ} 30'N$). Calculations made by Saito and Ozawa (1992) and Watanabe (1994) show that the magnitude of the eclipse of 637 was greater than that of the eclipse of 628, which contradicts with the reports in the Nihongi, and they concluded that the description of the AD 628 eclipse in the Nihongi was an exaggeration.

There was also a record of a lunar occultation of Mars of AD 681 in the Nihongi. Comparing these records with the Chinese eclipse records of AD 616 and AD 702, we show that it is possible that the AD 628 eclipse was indeed total at Asuka, and we derive the Earth's rotation (the value of $TT - UT$ where TT is Terrestrial Time and UT is Universal Time) in the 7th century from these observations.

2. OBSERVATIONS AND CALCULATIONS

Stephenson (1997) obtained the values of $\Delta T = TT - UT$ from about 720 BC using mainly the ancient solar and lunar eclipses. According to the ΔT curve of his Fig. 14.4, the value of ΔT in the first half of the 7th century is about 4500 sec, but the figure also shows that there were few eclipse records used to derive the ΔT values in the 7th century, and the value does not fit with three points obtained from solar eclipses of around AD 700.

If we adopt the value $\Delta T = 4500$ sec in the first half of the 7th century, the magnitudes of the solar eclipses of AD 628 and AD 637 are 0.89 and 0.93, respectively. This is in accord with the calculations by Saito and Ozawa (1992) and by Watanabe (1994), but it contradicts with the eclipse records in the Nihongi as mentioned in Sect. 1.

Solar eclipses of AD 616 and AD 702 are recorded in China. The 616 May 21 solar eclipse is given as “chin” in Sui-shu (Annals of the Sui Dynasty). “Chin” usually means total, but it was also used for annular eclipses, and in fact the AD 616 eclipse was annular. The 702 September 26 eclipse is recorded as “almost complete” in Chiu-t’ang-shu (Old History of the T’ang Dynasty) and as “not complete and like a hook” in Hsin-t’ang-shu (New History of the T’ang Dynasty). It is assumed that the AD 616 eclipse was observed at Lo-yang (approximate longitude $112^\circ 24'E$, latitude $34^\circ 48'N$), and the 702 eclipse was observed at Ch’ang-an (approximate longitude $108^\circ 55'E$, latitude $34^\circ 15'N$).

From the condition that the AD 616 eclipse was annular at Lo-yang, the AD 628 eclipse was total at Asuka, and the AD 702 eclipse was not total at Ch’ang-an, the following ΔT values are derived:

Date	Place	Possible range of ΔT
616 May 21	Lo-yang, China	$2278 \text{ sec} \leq \Delta T \leq 3002 \text{ sec}$
628 April 10	Asuka, Japan	$2267 \text{ sec} \leq \Delta T \leq 2959 \text{ sec}$
702 Sept. 26	Ch’ang-an, China	$\Delta T \leq 1429 \text{ sec}$ or $2728 \text{ sec} \leq \Delta T$

The common range of the ΔT value for the three eclipses is $2728 \text{ sec} \leq \Delta T \leq 2959 \text{ sec}$, but since it is hard to believe that the ΔT value was constant from 616 to 702, we conclude here that the ΔT value was about 3000 sec in the 7th century as opposed to about 4000 sec given by Stephenson (1997).

By adopting the value $\Delta T = 3000$ sec, the magnitudes of the AD 628 eclipse and the AD 637 eclipse at Asuka are 1.00 and 0.88, respectively, which agrees with the records in the Nihongi.

There is another record in the Nihongi which supports our value of ΔT . A lunar occultation of Mars of 681 November 3 was recorded as “Mars was occulted” in the Nihongi. Our calculations show that actually Mars was not occulted at Asuka but the apparent distance of Mars’ center from the lunar limb at the closest approach depends on the adopted ΔT value as follows:

ΔT	Distance
3000 sec	34''
4000 sec	71''

The Moon’s age was 17.3 days and the Moon’s phase (fraction of the area of the apparent disk that is illuminated by the Sun) was 95%, but Mars’ altitude was 70 deg above the horizon and Mars’ magnitude was -1.3 so that Mars was bright enough to be seen near the Moon. Considering that the angular resolution of naked eyes should be usually better than about $60''$, $\Delta T = 4000$ sec cannot be accepted from the occultation report, but it is seen that $\Delta T = 3000$ sec is acceptable from the above calculations.

For the present calculations, $-13''T^2$ is adopted for the tidal term of the lunar mean longitude, where T is the time in centuries. This coefficient is the one obtained by Dickey et al. (1994)

from the analysis of the recent lunar laser ranging measurements, and it is consistent with that derived by Morrison and Ward (1975) from the comparison of the observations of transits of Mars and lunar occultations of stars which covered the period from 1677 to 1973. However it is questionable if this coefficient has been constant since the 7th century. The ΔT values obtained from the eclipse records depend on the coefficient of the tidal term. The dependence will be investigated elsewhere.

3. CONCLUSION

From the eclipse and occultation observations recorded in Japan and China, it is concluded that the ΔT value was about 3000 sec in the 7th century.

4. REFERENCES

- Dickey J.O., Bender P.L., Faller J.E., Newhall X X, Ricklefs R.L., Ries J.G., Shelus P.J., Veillet C., Whipple A.L., Wiant J.R., Williams J.G., and Yoder C.F. 1994, *Science*, **265**, 482–490.
Morrison L.V. and Ward C.G. 1975, *Mon. Not. R. Astr. Soc.*, **173**, 183–206.
Saito K. and Ozawa K. 1992, *Ancient Astronomical Records in China*, Yûzankaku (in Japanese).
Stephenson F.R. 1997, *Historical Eclipses and Earth's Rotation*, Cambridge University Press.
Watanabe T. 1994, *Solar and Lunar Eclipses Recorded in China, Korea, and Japan*, Yûzankaku (in Japanese).