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TIMING RECORDS OF ANCIENT LUNAR ECLIPSES IN CHINA AND LONG-TERM VARIATION OF THE EARTH'S SPIN SPEED

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ABSTRACT

The Chinese ancient accounts of timing observations of 48 lunar eclipses and the secular variation of the Earth's spin speed are discussed . A series of ΔT expressing the secular deceleration of the Earth's rotation was obtained. The average increase rate of length of the day is about 1.5 milliseconds per century.

Key Words : Earth's rotation, lunar eclipse.

I. INTRODUCTION

During the last about three decades, much research attention has been directed toward the long-term variation of the Earth's rotational speed and the non-tidal contributions in the variation based on ancient records of astronomical observations. The studies of the ancient records gave a preliminary scenery of secular variation of the Earth's rotation over twenty centuries before the 17th century. However, the distribution of ΔT values derived from the records is far from uniform, and some gaps exist in the data series. It is important to utilize more records of ancient astronomical observations to improve the precision and continuation of the data series, especially to study short time scale (hundreds of years or less) fluctuations of the Earth's rotation rate. There exist abundant records of ancient astronomical observations in ancient China. Some of them have preliminarily been utilized in previous works (Curott, 1966; Nowton, 1970, 1985; Stephenson, 1978; Morrison, 1978; Han et al., 1984; Li et al., 1985). The present article mainly discusses the records of lunar eclipses, which are recorded in the Chinese official history chronicles (the "24 Chronicles") distributed in the period from the A.D. 3rd century to 13th century, and selects some records that are considered reliable to deduce the variation of the Earth's rotational speed.

II. OBSERVATIONS OF ANCIENT LUNAR ECLIPSES IN CHINA

China has a long history about solar and lunar eclipses records. More than 700 observational records of about 400 ancient lunar eclipses have been found in historical chronicles prior to the late *Ming* Dynasty (mid-A.D. 17th century). The ancient astronomers paid attention to lunar eclipse in order to improve the calendar. Thus, lunar eclipses were usually recorded by professional astronomers in ancient capitals. Capitals of some dynasties are generally considered as the observational places in the study when the places was not given in the records, and hence the data should be relatively more precise and reliable. It is a pity that no more than a few dozen such recordings actually have the occurrence time of eclipse phase.

III. ANALYSIS OF THE RECORDS AND RESULT

The timing records of 133 eclipse phases were documented for the 56 lunar eclipses occurred in the period of A.D. 221 – 1617. Fifty four eclipses of them gather at two periods, one is from A.D. 221 to 596, another is from A.D. 948 to 1280. The records used in this paper are mainly from the observations of eclipses occurred in these two periods. We have found that few entries appear problematic. Some records contradicted to normal process of a lunar eclipse, such as the possible duration of certain phase. This may have occurred in the original observing or writing, or due to miscopying in succeeding versions of the documents. Such observations are excluded. Finally, 98 timing records of 48 lunar eclipses are considered more reliable and used in the study of the Earth's rotation.

It is convenient to express the variation the Earth's rotation in ΔT in terms of the ancient documented time of lunar eclipses. Under a unified time system, the same phase of a lunar eclipse is observed by all observers on the Earth. The timing of the observations was based, of course, on the contemporary time system at that time, which is normally the local apparent solar time. The evolution of time system through Chinese history is complex but has been fairly well studied, allowing the conversion of ancient time system to the Universal Time system, UT. The value of ΔT can be obtained through the comparison between converted timing records (to UT) and computed time of relevant eclipse phase according to Ephemeris Time system (ET). That is

$$\Delta T = ET - UT.$$

In order to reduce the error of the result as much as possible , the ΔT value is determined from the mean of results derived from the records of several eclipse phases for each eclipse.

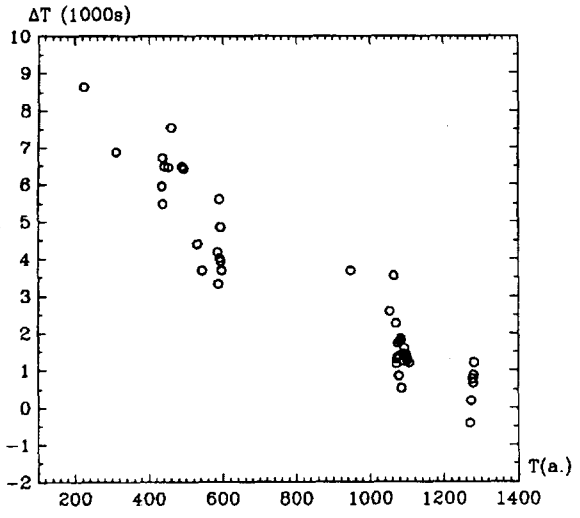

Fig. 1.— The distribution of ΔT derived from timing observations of 48 ancient lunar eclipses in China.

The resultant values which derived from 98 timing records of 48 lunar eclipses are shown in Fig. 1 (the values of ΔT are related to the orbital acceleration of the Moon, $\dot{n} = -26.0''/cy^2$, where cy is time in century).

IV. CONCLUSION AND DISCUSSION

In Fig. 1, the distribution of ΔT values obtained from Chinese timing records of 48 ancient lunar eclipses clearly shows the secular variation trend of the Earth's rotation from the A.D. 3rd to 13th century. Only the ΔT value derived from a record of lunar eclipse in 1270 constituted a larger departure from the values. The departure is more than 3 times of the standard error of the data series in this paper, so it will be deleted when the variation of length of the day (l.o.d.) is discussed. There is no larger dispersion in the distribution of the ΔT values derived from other 47 eclipses. This shows that the Chinese timing records of ancient lunar eclipses are worth for the study of variation of the Earth's rotation. Average increase of l.o.d. variation in period of A.D. 552–1900 (A.D. 552 is the average epoch of the data in this paper) due to the secular slow down of the Earth's rotation is about 1.5 milliseconds per century (ms/cy) according to the result. The authors noticed that the average increases of l.o.d. derived from lunar eclipses distributed in two periods (A.D. 3rd–7th century and A.D. 10th–13th century) are little different. The result from the former is about 0.2 ms/cy more than one from the latter. The occurrence period of the lunar eclipses distributed in the second period are closed to the one of medieval Islamic solar and lunar eclipses which occurred during the period of A.D. 9th–11th century. Stephenson et al. (1989) have studied the timing records of 36 solar and lunar eclipses and obtained the average increase of l.o.d., 1.4 ms/cy (the average epoch of the data is A.D. 950).

The two results support the notion that the non-tidal contributions in the variation of l.o.d. is about −1.0 ms/cy in the past 10 centuries or more (the average increase of l.o.d. due to tidal effects is about 2.3 – 2.4 ms/cy in the theory of the Earth's rotation). Stephenson et al. (1989) considered that a large fluctuation had appeared in the variation of the Earth's spin rate in about 10th century, the increase of l.o.d. was larger before about the 10th century. This will be important for the studies of the Earth's rotation and of the variation of contributions of non-tidal effects on the rotation . The result of this paper does not give a strong support for Stephenson's view although it shows that the increase of l.o.d. in the period of the A.D. 3rd – 7th century is slightly more than one millisecond per century than that in the period of A.D. 10th – 13th century. We think that the final conclusion of the phenomenon needs more studies of more ancient data.

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