

HISTORIC VARIATIONS IN THE ROTATION OF THE EARTH*

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The purpose of this work is to investigate changes in the rotation of the Earth in the past few thousand years. Since most available observations involve the Moon, study of the Earth's rotation is inseparable from study of the Moon's motion. Since it is doubtful that present theories of tidal friction account for the present acceleration (Spencer Jones, 1939; Van Flandern, 1970; Pariisky *et al.*, 1972) of the Moon, we cannot safely assume that consequence of the theories which says that tidal friction has been almost constant.

Past studies of historic changes have relied heavily upon old records of solar eclipses. Such studies have suffered from three serious defects: (1) Extensive errors in quotation. For example, it is widely claimed that Fotheringham (1920) published an observation of the eclipse of –1062 July 31 made at Babylon; Fotheringham actually concluded that the published text was *not* an observation of the eclipse made at Babylon. (2) Use of ancient texts that were actually religious propaganda, for example. (3) Use of records that are not dated explicitly or by the historical context. Many past studies have used such records on the assumption that the 'correct' date is the one that requires the smallest negative accelerations; this assumption is untenable.

This work that I have published on this subject (Newton, 1970) is an analysis of about 250 astronomical observations made between –762 June 15 and 1241 October 6. The observations include places where solar eclipses were large or total, conjunctions or occultations involving the Moon, conjunctions or occultations involving Venus, magnitudes of solar and lunar eclipses, times of various phases of solar and lunar eclipses, and times of equinoxes and solstices. All observations except the places of solar eclipses were made by professional astronomers. Records of solar eclipses are used in the final calculations only if they can be dated on the basis of the text alone, and if there is no serious reason to question the truthfulness of the record.

The results indicate that the acceleration \dot{n}_M of the Moon has averaged about –42 sec of arc per century per century since –762; this is with respect to an ephemeris time scale. During the same period, the acceleration $\dot{\omega}_e$ of the Earth's spin has averaged about –25 parts in 10^9 per century and the part that cannot be attributed to tidal friction has averaged about +23 parts in 10^9 per century. Unfortunately, the equations that determine \dot{n}_M and $\dot{\omega}_e$ together are poorly conditioned, and it is not possible yet to follow their time behavior with much detail.

However, the parameter $D'' = \dot{n}_M - 1.6073 \times 10^9 (\dot{\omega}_e/\omega_e)$, in which ω_e is the spin rate, is strongly determined and we can follow its time dependence in considerable detail.

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In the work that has been published, I formed fourteen independent estimates of D'' for epochs ranging from -700 to $+1050$. D'' increased slowly from -700 to about $+700$ and decreased rapidly from then to 1050 .

This conclusion is rather unexpected, and it is desirable to test it by the use of further data. In work that is being written for publication elsewhere, I examined about 2000 records of solar eclipses, mostly in the time period from 400 to 1200. From these, I selected about 380 as being of particular value. I divided the total sample of about 380 records into 12 groups with mean epochs ranging from about 400 to about 1250, and I estimated a value of D'' for each group. The time dependence of the resulting values of D'' agrees excellently with that found in the first study; the decline in D'' apparently continued at least through 1250.

In sum, the results of the study of historic variations show that there was a large and sudden change in the behavior of either \dot{n}_M or $\dot{\omega}_e$ or both about the year 700. From the statistical point of view, the confidence level of this change is quite high. The standard chi-square test says that the result is significant at the level of 99.99% or more. It will be necessary to examine the fundamental physical processes in detail before we can say with high confidence whether the change was in one of the accelerations, or whether it was perhaps in some other important property of the Sun-Earth-Moon system.

References

- Fotheringham, J. K.: 1920, *Monthly Notices Roy. Astron. Soc.* **81**, 104.
 Newton, R. R.: 1970, *Ancient Astronomical Observations and the Accelerations of the Earth and Moon*, The Johns Hopkins Press, Baltimore.
 Pariisky, N., Kuznetsov, M., and Kuznetsova, L.: 1972, this volume, p. 240.
 Spencer Jones, H.: 1939, *Monthly Notices Roy. Astron. Soc.* **99**, 541.
 Van Flandern, T. C.: 1970, *Astron. J.* **25**, 657.

DISCUSSION

Wm. Markowitz: Dr Melchior asked whether secular acceleration of the Earth's rotation derived by Spencer Jones agreed with the results from corals. Results from work of several authors (Spencer Jones, Brouwer, van der Waerden) indicate an increase of about $1.5 \mu\text{s}$ in length of day per century during the last 20 centuries. Value from corals during past 300 000 000 yr is in reasonable agreement, although not as well determined.