Uses for ancient eclipse records

In spite of arguments about the astronomical interpretation of ancient eclipse records, one thing is certain — the more that can be found, the more useful they will be.

THE sport of wringing information of value in astronomy from historical records has long since been made respectable. It is even tempting to wonder whether the present understanding of supernovae would have been possible without the Chinese record which was recognized, in retrospect, to be a first-hand account of the star from which the Crab nebula was formed (but with a pulsating neutron star left over). The reality of the Maunder sunspot minimum in the early seventeenth century was established (by J. Eddy) by poring over ancient records, this time, to be sure, contemporary astronomical records.

The use of ancient records of solar and lunar eclipses is even longer established. Robert R. Newton begins an elegant paper on the acceleration of the Earth's spin (*Geophys. J. R. astr. Soc.* **80**,313-328; 1985) with an account of how Edmund Halley concluded from some observations of lunar eclipses due to Ptolemy that the length of the year had been decreasing. This implied, said Halley, "the necessity of the world's coming to an end, and consequently that it must have had a beginning, which hitherto has not been observed in anything that has been observed in Nature". For his part, Newton wonders how Halley could have come to the conclusion that the Sun was accelerating (when in reality, the opposite is the case) and asks a little wistfully that "if any reader knows the basis on which Halley found the Sun is accelerating, I would appreciate hearing of it".

Since much of Newton's own argument is concerned with demonstrating the pitfalls of using the records of eclipses, he should not be so surprised. The potential value of ancient eclipse data stems from the fact that they provide a nearly exact measurement of the relative longitude of the Sun and Moon (ideally zero for a solar eclipse and 180° for a lunar eclipse) at some distant epoch. In principle, the only changeable elements in this equation are the rate of the Earth's rotation on its axis and the angular velocity of the Moon, which are both affected by their mutual tidal interaction. In practice, so people have been arguing since Halley's time, it should then be possible to calculate from ancient eclipse observations the deceleration of the Earth's spin even as a function of time.

This is precisely what F.R. Stephenson and L.V. Morrison did at the Royal Society's meeting on rotation in the Solar System a year ago (*Phil.Trans. R. Soc.* **A313,** 47; 1984). Their objective, like Newton's now, was to identify the secular change, whatever it may be, in the rate of the Earth's rotation. One obvious complication is that the calculated secular deceleration of the Earth's rotation attributable to tidal action is a mere 2.4 milliarc-seconds per century.

Stephenson and Morrison used a wealth of records, ancient and modern, spanning almost 2,700 years. The earliest data come from Babylonian records, both of solar eclipses and the Moon rising while already eclipsed, with a modest admixture of Chinese information. With the advent of telescopes (and accurate timekeeping) in the past three centuries, occultations of stars by the Moon have become a more accurate way of pinning down the data. One of the striking features of the data set is the poverty of the information available for the medieval period.

The mechanics of Stephenson and Morrison's analysis is outwardly simple. One neat way to describe it is by the difference between Universal Time (UT), astronomical time measured strictly by the Earth's rotation, and Ephemeris Time (ET), the smoothed version of UT introduced just over thirty years ago to provide a more uniform measure of the independent variable in the dynamics of the Solar System.

The transformation from one system to the other requires that allowance should be made for the acceleration of the Moon's longitude, supposed to be entirely the consequence of tidal interaction, which was originally taken to be −22.44 arc-seconds per century (and which Stephenson and Morrison think should be 26 in the same units, based on observations of the transit of Mercury). Then the difference between UT and ET at any stage should be a measure of the departures of the rate of the Earth's rotation from a fixed value.

The upshot of the Stephenson and Morrison analysis seems to be clear — for the past millennium, the secular change in the length of the day has amounted to 1.4 ms per century, but before that, the rate was greater, more like 2.4 ms per century. It goes without saying that, on the face of things, the more ancient records are in some ways the most telling — the difference between UT and ET increases with the square of the time elapsed.

And of course, the most ancient records do not depend on the timekeeping (if any) used for making the observations; provided that the date of observation is known (or can be calculated or inferred), the equations for the motion of the Sun and the Moon will suffice to fix the time at which an eclipse occurs so long as it is known where the event was seen (and so long as it can fairly be assumed to have been a total eclipse).

Newton's argument sets out to discard eclipse data that are for one reason or another unreliable. He spends more than a page of his printed paper demolishing the case for using as a datum the eclipse whose description is included in a poem by the Greek soldier-poet Archilochus, who is known to have divided his life between two islands in the Aegean. The date is what perplexes Newton, who concludes that the eclipse described was either that of 6 April, 647 BC or that of 15 April nine years later, and that a suitable choice of values for the acceleration of the Moon's longitude would have made it visible from either island. Both Dicke and Lyttleton, Newton says, used this eclipse in different connections.

Newton has some good clean fun at the expense of what he calls the "identification game" supposed to have been invented by Airey more than a century ago, in which people have been used to assuming a value for the lunar acceleration, using this to calculate past eclipses, using eclipse records to pick on one and using the result to recalculate the lunar acceleration. It is not surprising, Newton says, that the answer is usually not very different from the starting value, for the argument is circular. He is probably right to insist that such data do need careful scrutiny before they are used for serious purposes. The merit of his own analysis is its use of data such as those gathered by the Babylonians for the definition of their calendar consisting of measurements of the angular displacement between the Sun and the Moon at new moon.

Newton may have overlooked the way in which safety can be found in numbers, for within the uncertainties his conclusion is not sharply different from that of Stephenson and Morrison. Briefly, he concludes that the deceleration of the Earth's spin has declined by a factor of about two since 500 BC. He suggests that geomagnetism may provide the explanation. A host of others, such as post-glacial isostacy, would fit the bill. What stands out is that the ancient records, consistent among themselves, still have much more weight in estimating the secular deceleration of the spin than the more accurate modern measurements, befogged as they are by the irregular variations.

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