OBSERVATIONS OF THE PERFORMANCE OF PENDULA AT THE TIME OF THE 2002 DECEMBER 4 SOLAR ECLIPSE IN SOUTH AUSTRALIA

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Summary

It has been claimed that pendula exhibit anomalous behaviour at the time of solar eclipses. The claims have been that Foucault pendula deviate from the regular motion of their plane of oscillation and that pendula, more generally, change their oscillatory period. At the time of the 2002 December 4 solar eclipse, we made observations of the operation of a Foucault pendulum and a pendulum clock at the University of Adelaide. We were able to set an upper limit of one degree on the deviation of the oscillatory plane of the Foucault pendulum at eclipse time when compared to observations immediately before and after the partial eclipse phases. Our limit on any change of pendulum time periods associated with the eclipse was one part in one hundred thousand.

KEY WORDS: pendulum, anomaly, eclipse.

Introduction

Total solar eclipses are unique phenomena. They are infrequently observed and each eclipse has its own particular circumstances which are not reproducible at another time. As a result, phenomena may be claimed to have been observed at eclipse time which are difficult to reproduce or disprove. Such anomalous phenomena have been associated with the operation of pendula at the time of total solar eclipses (eg Saxl & Allen 1970). In particular, it has been claimed that the regular change of the plane of oscillation of a Foucault pendulum may be disrupted at eclipse time, or the period of the swing of any pendulum may be changed. If confirmed, these observations would seem to require new physics and, hence, claims of such unexpected phenomena have aroused considerable interest and have retained their interest in the literature.

Foucault pendula are free to swing in any plane and their plane of oscillation exhibits a slow progressive rotation due to the daily rotation of the Earth. An abrupt deviation from the regular movement of the plane of oscillation of a Foucault pendulum was reported by Allais (1959) following observations at the time of the 1954 June 30 eclipse. He observed a change in the swing from a plane to an ellipse and a change in the direction of the major axis of the ellipse from the expected plane by 16 degrees at the onset of the eclipse. This change was observed to continue until roughly the maximum of the eclipse. It is noteworthy that this effect was observed in Paris, a considerable distance from the path of totality which passed through southern Sweden at its closest approach to Paris. At the time of the 1961 February 15 eclipse, it was reported (Jeverdan et al. 1981) that the period of a Foucault pendulum decreased by about 10 ms (in a period of close to 10s). Over the decades since these observations, a number of further observations have been made of pendula (or the local gravitational acceleration) at times of solar eclipse. The results have been inconsistent (see http://science.nasa.gov/newhome/headlines/ast06aug99_1.htm as accessed 9 March 2006).

On 2002 December 4, there was a solar eclipse which began totality over Africa and ended at sunset over Australia after passing over mid-South Australia, some 500 km north of the city of Adelaide. That distance from Adelaide was only about one half of the distance from Paris to totality at the time of Allais’ 1954 observations. The University of Adelaide had available a Foucault pendulum
which had been built for teaching and a Shortt pendulum clock, arguably the pinnacle of the pendulum clock makers art. These pendula were used to test for any unaccounted for changes in oscillation plane or pendulum period at the time of the eclipse.

The Foucault Pendulum

The Adelaide Foucault pendulum was built to demonstrate the effect of rotation of the plane of oscillation under teaching conditions. It was located within a wing of the Physics building of the University of Adelaide. Foucault pendula are free to swing in any plane. The plane of oscillation of the pendulum rotates as the Earth rotates, a phenomenon which is most easy to imagine at the poles when one might think of the Earth rotating below the pendulum. Our pendulum was in a style described by Stong (1964) with a Charron ring arrangement which ensured that, for each swing, an electromagnet beneath the pendulum bob was energised to transfer energy to the swing and maintain the oscillation. This can continue indefinitely and has been run for periods of years, as opposed to

undriven pendula often found in science museums which are restarted at rather short intervals to maintain the swing. In the context of this observation, the Charron ring touches the wire pendulum suspension and might arguably reduce any elliptical motion in the swing. Such an effect would, however, be minute. The orientation of the plane of the oscillation is read by an observer against a calibration scale. We find that independent observers agree within an uncertainty of one degree.

The plane of oscillation of a Foucault pendulum should rotate through 360 degrees in 24 hours divided by the sine of the observation latitude. For our pendulum, the plane rotated at a rate of 8.461 degrees per hour over the week of the eclipse. This correctly gives the latitude of Adelaide (see Fig. 1).

The Shortt Clock

The University of Adelaide has a Shortt free pendulum clock. This consists of two pendula. One sets the time period and swings in an evacuated environment. The second, nominally identical, pendulum drives a mechanical clock and is set every 30 seconds by the primary pendulum through a series of electromechanical relays which ensure that the primary pendulum is essentially a free swinging pendulum. Such clocks were the pinnacle of mechanical timekeepers and this particular clock was the South Australian time standard in the 1930s.

![Figure 1](image-url)
Results

The eclipse was visible in South Australia on 4 December 2002 over a period of time from about 18h40m until sunset at approximately 20h00m. Where totality was visible (some 500 km north of Adelaide), this lasted for up to 30s at approximately 19h40m. At Adelaide, first contact was at 18h39m and the maximum of the eclipse of 88.2% occurred at 19h37m. Measurements of the plane of oscillation of the Foucault pendulum were made at intervals of approximately 10 minutes over the period of the eclipse and at infrequent intervals over the preceding two days and the following week. Fig. 1 shows the orientation of the plane of oscillation over the total time period and, as noted above, the overall rotation of the plane is consistent with expectations. There are however variations which are not explained. These are emphasised when deviations from the overall trend are examined. Fig. 2 shows the deviations of the orientation of the plane from the expected trend over the extended period of time. We do not know the origin of these deviations. They are not sudden, random, changes but must reflect some environmental effects. Fig. 3 shows the deviations over the period of time from immediately before the eclipse to immediately after. Those deviations are not out of line with the deviations over the longer period although they are some 12 degrees from the long term trend line. There is, however, no suggestion that any sudden change occurred at the time of the eclipse at a level of more than the noise on the data, conservatively 2 degrees per sample.

![Figure 2. Deviations from the overall trend of figure 1.](image)

Allais (1954) reported that at the time of the eclipse, his Foucault pendulum swing became elliptical. We videotaped the Foucault pendulum over a four hour period which covered the time of the eclipse. This enabled us later to determine the pendulum period over the time of the eclipse. Over the full four hours of videotaped data, the mean period for 100 swings was 269.85s with a standard error of 0.12s. In the hour which included the eclipse, the 100 swing period was 270.05s with a standard error of 0.2s and, over the 15 minutes including totality in South Australia, it was 270.00 with an uncertainty of 0.2s. There was no visual evidence for any elliptical motion of the pendulum.

Our observations of the Shortt clock were made by checking the time of its 30 second impulse (used to reset the slave pendulum against the free pendulum in an evacuated vessel) against a regular pulse from a rubidium atomic clock. The deviation between the two was monitored to better than a microsecond. The two clocks drifted against each other with a regular rate. We removed that
regular drift and examined residual differences over the period of a week containing the time of the eclipse. These residuals generally consisted of a slow deviation from a linear drift rate plus deviations from one sample to the next of the order of two milliseconds (Fig. 4). Fig. 5 shows data for the day of the eclipse. There is a slow drift in the residuals plus the millisecond level sample-to-sample noise. Fig. 6 shows this drift more clearly as a running mean over eight 30s samples is displayed. If we take a period of one hour through the time of eclipse maximum and compare the expected deviation based on periods before and after the eclipse, we find a maximum effect due to the eclipse of 0.1 ms per sample of 30s duration. The averages of the deviations from the long term trend of the Shortt clock for progressive half hour periods over the eclipse were 0.20 ms, 0.31 ms, 0.16 ms, and 0.37 ms to be compared with the average of the following two hours of 0.36 ms.

It has been suggested that meteorological effects (atmospheric pressure, wind), due to the removal of atmospheric solar heating over the eclipse path, might affect some pendula and explain some of the observed anomalous results. The mechanism could be associated with induced draughts in the large architectural spaces which enclose undriven conventional Foucault pendula. Our Foucault pendulum was in a small room and enclosed in a perspex case and we would not expect it to be
susceptible to such an effect. On the other hand, our results for the time deviation of the Shortt clock did show some apparent correlation (over periods of the order of hours) with atmospheric pressure over the eclipse period (Fig. 7) at a low level (milliseconds per millibar). Measurements from other times also suggest that there is indeed some small pressure coefficient in the drift of the clock. However, unlike some eclipse reports (eg Van Flandern & Yang 2002 who reported a 6 mb pressure increase with the 1999 August 11 eclipse at a distance of 700 km from totality), there was no significant pressure deviation at eclipse time. This could be due to the fact that the eclipse occurred close to sunset.

Discussion

Reported anomalous operations of pendula at the time of eclipses have fallen into two categories. We have set stringent limits on any such effects at the time of the 2002 December 4 eclipse.
One claimed anomaly is in the rate of rotation of the plane of oscillation of a Foucault pendulum. This has been reported to deviate by up to 16 degrees from that which might be expected. Our observations set a limit on any such effect for the South Australian eclipse of 1 degree when compared with pendulum oscillation before and after the observable start of the eclipse and 12 degrees when compared to the long term rotation of the plane of oscillation.

A second reported anomaly has been in the period of the pendulum. For our Foucault pendulum, we found a period of 2.700 s with an uncertainty of 0.002 s at the time of eclipse maximum compared to a long-term period of 2.6985 s with an uncertainty of 0.0012 s. There is thus no evidence for anomalous behaviour in the period of our Foucault pendulum at a level of one part in one thousand. Our measurements with a Shortt clock put a limit of 0.1ms to any deviation over a 30s interval at the time of the eclipse, representing a limit of better than one part in one hundred thousand for any anomalous effect in the period of a pendulum at eclipse time. We reiterate that, though our site was not in the line of totality, it was much better placed than the original observations of Allais.

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