The Diameter of (9) Metis from the Occultation of SAO 190531

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Abstract: The observations in this paper were carried out as part of a program co-ordinated by the Occultation Section of the Royal Astronomical Society of New Zealand.

On 6 August 1989 minor planet (9) Metis occulted the magnitude 8.7 star SAO 190531. The occultation was observed by two visual observers in Tasmania, and at one photoelectric and two visual sites in New Zealand. From the five chords obtained we have deduced an average cross-sectional diameter for this minor planet of 173.5 km at the time of the occultation. This is in good agreement with previous radiometric and polarimetric results.

1. Introduction

On the evening of 1989 August 6 the asteroid (9) Metis passed in front of the magnitude 8.7 star SAO 190531. The path of this event, predicted by Edwin Goffin (1988) through comparison of the asteroid's ephemeris with the star position from the SAO catalogue, passed across the North Island of New Zealand, the Tasman Sea and southern Victoria. A subsequent prediction by David Dunham (1989) of the International Occultation Timing Association, using a USNO ZZ star position, placed the path across the South Island of New Zealand near Dunedin. The difference between the two paths is about 0.7 arcsec, corresponding to about 700 km on the surface of the Earth.

Although Metis is a low numbered minor planet, there is not a great deal of published data concerning it. Indeed, even the 'Asteroids II' database (Lagerkvist *et al.* 1987), does not list a diameter for Metis, although previous radiometric and polarimetric measurements have suggested a value around 168 km. However, in 1984 an occultation of a star by Metis was observed by at least seven observers in Europe. Kristensen (1984) has derived an ellipsoidal profile with major and minor axes of 210 and 170 km from these observations.

2. Updates

Two update plates were obtained by Robert Hindsley at the Black Birch Astrometric Observatory on 1989 July 26 and 28. Because major problems existed with the measuring engine at the time, the results of these updates were not as reliable as usual. Both plates indicated a substantial southward path shift of well over one arcsec. While the size of this shift was regarded as suspect, our previous experience suggested that its *direction* was probably correct. For this reason a number of visual and photoelectric observers were alerted throughout New Zealand, Victoria and Tasmania.

3. Observations

SAO 190531 has a listed visual magnitude of 8.7, while Metis was expected to be about magnitude 9.5 at the time of the occultation. The expected decline in brightness at occultation was therefore about 1.2 mag. Using Goffin's quoted diameter for Metis of 168 km, the maximum duration of the occultation was expected to be 15.4 s.

The occultation was observed at three sites in New Zealand, and two in Tasmania. Observers used visual timing methods (typically shortwave radio and tape recorder), except at Adams Lane Observatory, where photoelectric monitoring in Johnson V was carried out. Details of the sites at which positive occultations were recorded are listed in Table 1, together with the two 'constraining' northern and southern sites.

Several other visual observers who were clearly within the occultation band failed to record the event. This was probably due to the less than ideal conditions at these sites, which made the small drop in magnitude at occultation difficult to recognise.

Table 2 gives the times of immersion and emersion recorded by each of the observers. No correction for reaction time has been made to the visual timings. The integration time for the photoelectric observation was one second, leading to an accuracy of these timings of ± 0.5 s. This is probably slightly better than the accuracy of the visual timings.

Table 1. Observing Sites

Site No.	Location	East Longitude	Latitude	Altitude (m)	Observer	Telescope (cm)
–	Palmerston N., NZ	175°38′02.4″	–40°22′44.2″	34	N. Munford	30
1	Badger Head, Tas	146 40 26.0	–41 06 12.0	5	P. Daalder	15
2	Pukerua Bay, NZ	174 53 50.9	–41 01 56.6	60	J. Priestley	20
3	Tawa, NZ	174 48 53.0	–41 10 34.0	76	P. Riley	35
4	Launceston, Tas	147 10 16.6	–41 27 25.5	47	M. George	20
5	Blenheim, NZ	173 55 53.5	–41 30 24.6	20	W. H. Allen	30
–	Hobart, Tas	147 25 55.0	–42 50 55.0	230	Hill/Dieters	100

Table 2. Observations and Residuals

Site No.	Universal Time Immersion	Emersion	Duration (s)	Residuals (km) Figure 1 Im	Em	Figure 2 Im	Em	Time Shift (s)
1	$10^{h}42^{m}53.3^{s}$	$10^{h}43^{m}01.8^{s}$	8.5	−4.7	−12.8	+4.2	−4.2	−0.4
2	10 40 20.8	10 40 33.0	12.2	+6.1	+14.6	−4.3	+4.3	−2.1
3	10 40 19.3	10 40 34.3	15.0	−6.2	+11.9	−9.1	+9.1	−1.4
4	10 42 49.8	10 43 02.7	12.9	+15.6	+1.1	+7.2	−7.2	−1.9
5	10 40 23.5	10 40 38.5	15.0	−11.8	−14.0	+0.9	−1.1	—

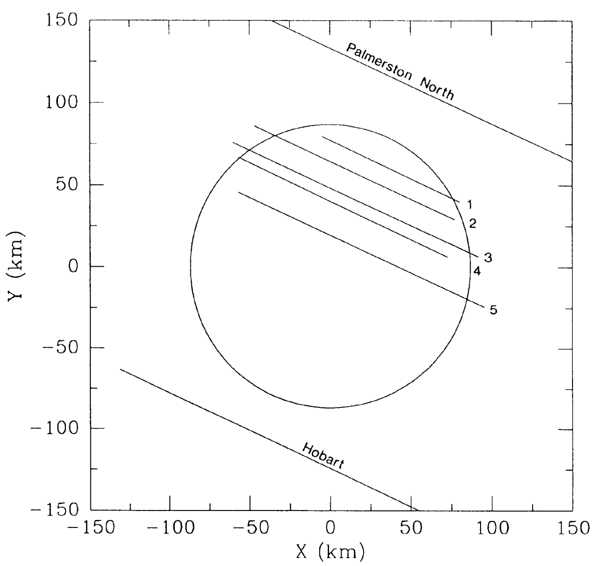

Figure 1 – Best circular fit with uncorrected data

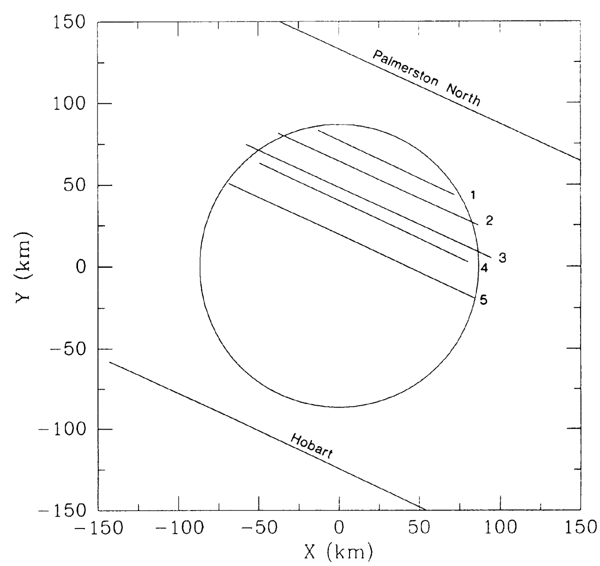

Figure 2 – Best circular fit with sliding chords

4. Analysis

The method of analysis involves projecting both the observer's locations and the centre of the minor planet's shadow onto the fundamental plane (Smart 1931). Each pair of timings then defines a chord across the projected profile of Metis. As the rotation period of Metis is about five hours (Lagerkvist *et al.* 1987), the profile will not have changed noticeably in the 2.5 minutes it took for the shadow to sweep across the Tasman Sea.

Fitting a reasonable outline to these chords allows us to estimate the projected size and shape of the minor planet. In the simplest possible model, that for a spherical minor planet, the apparent profile will be a circle. For an ellipsoidal minor planet, the profile will be an ellipse.

Figure 1 shows the raw observations plotted on the fundamental plane, together with the closest sites to record negative observations. A best fit circle to these data yields a diameter of 173.8 km, with residuals in the range 5–15 km (columns 5 and 6 of Table 2). In this fit, as well as those which follow, all observations were given equal weight.

Fitting the data in this way requires the use of three parameters—the x and y co-ordinates of the centre and the radius. The number of free parameters can, however, be reduced to one if the photoelectric chord is regarded as having higher absolute accuracy than the visual chords. In this model the distance from the centre of the 'accurate' chord to the centre of the circle completely defines the circular fit. Applying this model and keeping the photoelectric chord fixed, we obtain a radius of 175.4 km, in close agreement with that of the 'raw' solution.

We have so far ignored the reaction times of the visual observers. However, the visual chords can be expected to be late by amounts of order 0.5–2.0 s as a result of several factors: the previous experience of the observer in timing occultations, the degree of difficulty in seeing a relatively small magnitude drop, and the prevailing climatic conditions. Previous studies (e.g., Millis *et al.* 1983) have shown that the relative timing of immersion and emersion by visual observers is rather more accurate than their absolute timings. Thus, by allowing the visual chords to slide along their length while keeping the photoelectric chord fixed, we are able to derive an approximate average reaction time for each visual observer.

Allowing the visual chords to slide in this way yields a diameter for Metis of 173.5 km, with residuals now of order 1–9 km (columns 7 and 8 of Table 2). This fit is shown in Figure 2. Column 9 of Table 2 lists the shift in seconds required for this fit, and represents the average reaction time of the visual observer.

From this fit we have determined the difference between the predicted and actual positions of the occultation path. This difference can be ascribed to corrections to the Right Ascension and Declination of Metis at the time of the occultation. These corrections amount to −0.112 s in right ascension and −0.251″ in declination.

The foregoing analysis assumes Metis to have a strictly circular outline. However Kristensen's (1984) preliminary analysis implies a non-circular profile. We have fitted an ellipse to our data, but note that the insufficient north–south observational coverage does not allow us to distinguish adequately between a circular and elliptical solution. If only one chord had been obtained across Metis' southern hemisphere, a more definitive statement regarding shape might have been possible.

5. Discussion

Our analysis of the observations has given a value of 173.5 km for the diameter of that face of Metis seen at the time of the occultation. However, our conclusions about the shape of Metis are necessarily limited by the poor observational coverage. This makes it clear that good observational coverage is important in these events. Mobile amateur observers with portable telescopes are ideal for obtaining such coverage.

Examination of Figure 2 shows substantial discrepancies between the lengths of adjacent chords three and four. These may be resolved to a limited extent by reference to the observers' comments. Both observers noted significant seeing fluctuations, leading to some uncertainty in the time of the reappearance at chord 3, and in the time of disappearance at chord 4.

Our fitting procedure of course only allows us to determine the observers' average reaction times, which we note are commensurate with average times derived by Dunham *et al.* (1990). In that study a comparison was made between photoelectric chords and adjacent visual chords recorded by relatively inexperienced observers. Our results also confirm that the average reaction time quoted by a visual observer (typically 0.3 s in the present case) tends to be substantially smaller than its true value.

Acknowledgements

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