Mon. Not. R. astr. Soc. (1980) **192**, *Short Communication,* 47P–50P

An occultation by Charon

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Received 1980 May 30

Summary. An occultation of a 13th magnitude star by Charon (1978 P1) gives a minimum diameter of 1200 km for the satellite. The occultation light curve indicates that Charon is a solid body.

1 Introduction

A possible occultation of a 13th magnitude star by Pluto or its satellite, Charon, was predicted by Taylor (1979) to occur at about (UT) 0^h on 1980 April 7. Later predictions, communicated by Elliot (1980, private communication) and Taylor (1980, private communication) indicated that an occultation by Pluto itself would be unlikely since the closest approach of Pluto and the star would be almost 1 arcsec. However, near the predicted time of this closest approach, Charon would be at northern elongation and within 0.1–0.2 arcsec of the projected track of the star as viewed from South Africa. The prediction, based on plates taken by A. R. Klemola at Lick Observatory (Klemola & Elliot 1980) is shown in Fig. 1. Examination of errors involved in the orbital parameters of the Pluto–Charon system, and using the figures given by Harrington & Christy (1980) as an example of accuracy expected for the position of Pluto, showed that an error in the position of Charon of 0.2 arcsec was quite possible, consequently it was decided to attempt to observe the possible event.

2 Observations

Observations were made with the 100-cm telescope of the South African Astronomical Observatory at Sutherland, together with the high speed pulse counting photometer (Nather & Warner 1971) belonging to the Department of Astronomy, University of Cape Town.

The photometer was used in two channel mode, with a comparison star in the reference channel. This channel was periodically interrupted in order to check the telescope tracking. The main channel contained a filter approximating Johnson *B* followed by an Amperex 56DVP photomultiplier, with a focal plane aperture of diameter 18 arcsec. An iris diaphragm in the focal plane of the reference channel was set to a diameter of approximately 12 arcsec, thus any telescope drift would be noticed as a drop in counts in the reference channel prior to any effect on the main channel. Using two channels restricted the minimum possible integration time to 2 s, since data from both channels were printed and punched by a Teletype

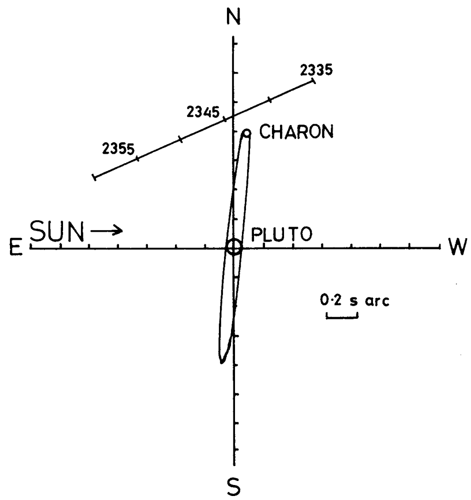

Figure 1. Occultation prediction for Cape Town, computed by D. Mink, M.I.T. The axes are marked at 0.2 arcsec intervals, while time marks on the projected path of the star (straight line) are every 5 min.

at 10 characters per second, however, it was felt that the two channel mode provided a secure check on photometric conditions and telescope tracking without causing any interruption of the main channel. Real time examination of the incoming data from both channels was possible by viewing a Tektronix display monitor.

Observations began at (UT) 22^h on 1980 April 6, almost 2 hr before the predicted time of closest approach, and continued until (UT) $0^h 30^m$ on April 7. Sky conditions were excellent.

3 Results

An occultation event centred at (UT) $23^h 39^m 28^s$ on 1980 April 6 and lasting 50 s was observed. Fig. 2 is the record of the event. The interruption in the reference channel was due to a check having been made on the accuracy of the centring shortly after it was noticed that the count rate in the main channel had fallen. No adjustment was necessary. The main channel sky brightness was 2755 counts/2 s, interpolated from measurements made 30 min

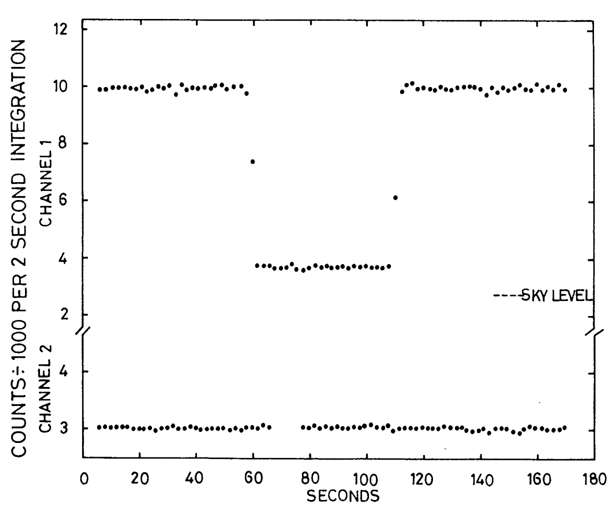

Figure 2. The occultation light curve. See text for details.

before and after the event, and was largely due to a 20-day old moon some 70° distant from Pluto. The combined magnitude of Charon and Pluto, determined from the count rate during the occultation, was $B = 15.05 \pm 0.05$ mag, while that of the occulted star was $B = 12.88 \pm 0.02$ mag. The photometry was calibrated following the occultation by measurements of several E region standard stars (Cousins 1973).

The proximity of the projected track of the star to Charon (Fig. 1) and the small relative positional errors between the star and Pluto determined from astrometric observations preceding the event (Klemola & Elliot 1980) prove that the occultation was by Charon and not by Pluto itself.

The occultation duration of 50 s corresponds to 0.055 arcsec, or 1200 km, thus the diameter of Charon is at least as great as this. If the event was central at Sutherland then the width of the track of visibility of the occultation on the Earth was about 1500 km; the negative observation by Moore (1980), made in England, implies that the diameter of Charon does not exceed approximately 18 000 km, however, a much smaller upper limit is derived below. It is a great pity that no other observations from the southern hemisphere appear to have been attempted.

4 Discussion

Christy & Harrington (1978) speculate that Pluto may have originally been a satellite of Neptune; and Charon may have broken off from Pluto when the latter was ejected from orbit around Neptune. An alternative hypothesis is that Pluto is not a planet at all but instead the remains of a comet, with Charon part of the nuclear region of the comet that has broken away, possibly very recently. However, the abruptness of the occultation ingress and egress, and the lack of light variations during occultation itself, would indicate that Charon is a single solid body rather than a swarm of smaller bodies or a smaller body with an extensive gaseous envelope. In the discussion below it will be assumed that Pluto and Charon are spherically symmetrical and have equal densities and albedos.

With Charon 1.7 ± 0.1 mag fainter than Pluto (Thomsen & Ables 1978), and using the orbital parameters given by Harrington & Christy (1980) the minimum diameter of 1200 km determined here for Charon corresponds to a minimum diameter for Pluto of 2600 km. Arnold, Boksenberg & Sargent (1979) measure the diameter of Pluto to be 3000 ± 400 km assuming no limb darkening and 3600 ± 400 km assuming limb darkening following a cosine law. An upper limit of 4000 km can therefore be assumed with reasonable confidence. Table 1 gives the derived densities and albedos for these two limits, together with values for diameters of 3000 and 3600 km.

Soifer, Neugebauer & Mathews (1980) confirm earlier reports that methane ice is the dominant constituent of the surface of Pluto. For a surface completely covered in methane ice the geometric albedo at wavelength 2 μm will be near 0.40, implying a lower limit for the

Table 1. Physical parameters of Pluto and Charon.

Pluto diameter (km)	Charon diameter (km)	Density (g cm^{-3})	Albedo (2 μm)
2600	1200	$1.3^{+1.0}_{-0.7}$	0.55 ± 0.2
3000	1350	$0.8^{+0.6}_{-0.3}$	0.40 ± 0.15
3600	1650	$0.5^{+0.3}_{-0.2}$	0.25 ± 0.1
4000	1800	$0.35^{+0.2}_{-0.1}$	0.20 ± 0.1

diameter of Pluto of 3000 km. The low densities in Table 1 indicate that Pluto is largely composed of frozen volatiles. With 0.35 as a reasonable lower limit for the density an upper limit of 4000 km is obtained for the diameter. The corresponding limits for Charon are then 1350 and 1800 km.

The evidence available at present indicates that Pluto and Charon form a 'double planet' system with probable diameters 3600 and 1650 km respectively, separated by 20 000 km. Observations of the transits and occultations which will occur when the Earth passes through the orbital plane of Charon should improve these figures and help elucidate the true nature of the system.

Acknowledgments

I am very grateful to Drs J. L. Elliot and G. E. Taylor for communicating predictions for the occultation.

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