

THE SATELLITE OF PLUTO

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ABSTRACT

Pluto appears to have a faint satellite with an orbital period of approximately 6.4 days and a mean distance of 15 000–20 000 km.

I. OBSERVATIONS

In 1978 a regular series of astrometric observations of the planet Pluto was begun with the U.S. Naval Observatory 1.55-m astrometric reflector at Flagstaff, AZ. These plates are to be used to obtain absolute positions of the planet, with the reference star positions being obtained via a cascading process through the twin 20-cm astrograph in Washington, DC. During the first season, plates were obtained on three nights in April and May 1978. On each night, a blue sensitive plate (GG13 filter+IIaO emulsion) and a yellow sensitive plate (GG14+IIaD emulsion) were obtained, with three exposures per plate. While measuring these plates on the STARSCAN automatic measuring machine on 22 June 1978, the first author noticed that the images were consistently elongated, in that there was a faint southerly extension on all exposures on 13 and 20

April, and a faint northerly extension on all exposures on 12 May. After ruling out guiding problems by noting that all stellar images were round, and ruling out a faint background star by examining the Palomar Sky Survey prints, the possibility of a satellite was suggested.

Verification was then sought on plates of Pluto taken previously for other projects. Plates had been taken with the 1.55-m reflector in 1965 and 1971 in an attempt to measure the diameter of Pluto at the times of occultations and in a series in 1970 to study the relative motion of the photocenter of the planet. Because the elongation in 1978 was only of the order of $0''.7$ on the best images, it was realized that any elongation could be detected only under conditions of very good seeing. Nevertheless, such an elongation was detected and a direction estimated on plates from two nights in 1965 and five nights in 1970, with the 1970 series suggesting

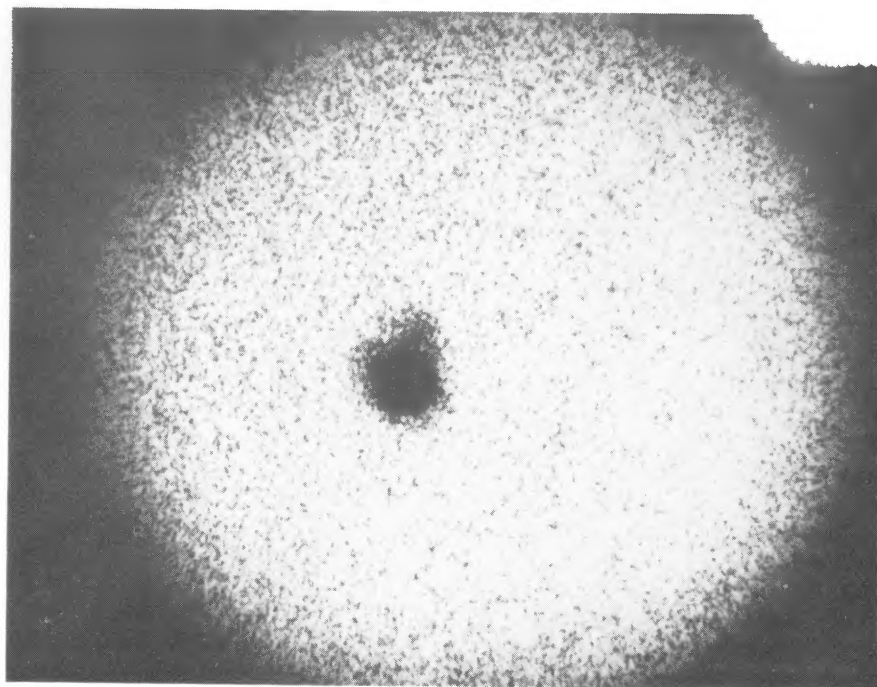


FIG. 1. Image of Pluto from plate taken 2 July 1978 with USNO 1.55-m astrometric reflector; magnification is approximately 100 times. Satellite appears as flare on planet image in about 12:30 position.

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TABLE I. Predicted and observed positions of Pluto satellite.

Date		P_{calc}	P_{obs}	D_{calc}	D_{obs}
1950 Mar	22.20	120°		0".21	
1965 Apr	29.16	167	160°	0.72	
1965 May	1.15	8	10	0.46	
1970 Jun	13.17	171	160	0.76	
1970 Jun	15.17	23	20	0.31	
1970 Jun	16.17	353	350	0.74	
1970 Jun	17.16	338	340	0.58	
1970 Jun	19.16	176	170	0.69	
1978 Apr	13.31	172	170	0.79	
1978 Apr	20.29	164	160	0.73	
1978 May	12.22	350	350	0.80	0".7
1978 Jul	1.20	14	10		
1978 Jul	2.17	352	350	0.80	0.8
1978 Jul	5.15	175	175	0.76	
1978 Jul	6.00	162	166	0.71	

a period of just over six days. However, the seeing did not permit a reliable estimate of the extent of the elongation on any of these plates.

Following these initial observations, Pluto was observed every possible night by C.C. Dahn with the 1.55-m reflector, even though it was well west of the meridian at the end of evening twilight. Definite elongations were observed on two nights, and conditions were sufficiently good on 2 July to permit another estimate of the extent of the elongation. Estimates by various observers ranged from 0".8 to 0".9, with the generally agreed best estimate being the lower value. Figure 1 shows the best image obtained that night. This elongation corresponds to 17 000 km at the distance of Pluto, a factor of 3 greater than the most likely maximum diameter of the planet permitted by the negative occultation observations (Halliday *et al.* 1966), virtually ruling out the possibility of any effect produced by rotation and variable surface features.

On 6 July, J.A. Graham photographed the planet at the prime focus of the Cerro Tololo 4-m reflector. He reported an elongated image with a mean diameter of 1".6, an axis ratio slightly less than 2 : 1, and a position angle of approximately $166^\circ \pm 5^\circ$. This further confirmed the reality of the image phenomenon, though not its interpretation as a satellite. Subsequently, on the same day, Captain J.C. Smith, USN, announced the discovery to the Navy, the astronomical community, and the media.

II. INTERPRETATION

In an attempt at an initial interpretation, it has been assumed that the 6.3867-day period associated

with the light curve (Andersson and Fix 1973) also applies to the satellite, that the orbit is circular with a radius equal to the maximum observed separation, that the time and direction of maximum elongation correspond to nodal passage, and that the inclination is high enough to permit only limited directions of elongation but not so high as to affect the light curve. Therefore the following elements have been adopted:

$$\begin{aligned}
 a &= 0".8 \text{ at a distance of 30 AU,} \\
 P &= 6.3867 \text{ days,} \\
 e &= 0.0, \\
 \omega &= 0^\circ, \\
 i &= \mp 105^\circ \} \text{ with respect to the plane of the} \\
 \Omega &= 350^\circ \} \text{ sky at } \alpha = 13:30, \delta = +10^\circ.5.
 \end{aligned}$$

The inclination to the ecliptic is approximately 115° or 55° , with the pole of the orbit lying near either $\alpha = 8^h$, $\delta = -5^\circ$ or $\alpha = 19^h$, $\delta = 35^\circ$, both in the domain of the pole of rotation of Pluto suggested by Andersson and Fix (1973).^{*} Using these elements, an ephemeris has been computed for the times of all positive observations, as well as for the time that Kuiper (1950) attempted to measure the diameter of Pluto at the Palomar 5-m reflector. The predicted position angles and separations, along with those observed if any, are given in Table I. The agreement in position angle, considering the difficulty of the measurement, is remarkable.

The above period and mean distance yield a mass for Pluto plus satellite of approximately $200\,000\,000^{-1}$ Solar masses (about 0.0017 Earth masses). If the diameter is approximately 3000 km, as suggested by Cruikshank, Pilcher, and Morrison (1976), based on an albedo of around 0.5, then the mean density of the planet is approximately 0.7 times that of water. This suggests that Pluto is predominantly frozen volatiles, similar to satellites of the outer major planets. If it is further assumed that the light variation is indeed due to rotation of the planet (the satellite could be no more than 1.6 magnitudes fainter in the visual to produce a variation of 0.22 in the total V), then the satellite revolution and the planet rotation are synchronous. For a close satellite, such synchronous revolution/rotation would be stable (especially if the planet were somewhat prolate), with the planetary rotation rate easily adjusting to variations in the satellite period caused by secular variations in the mean distance. It is difficult to deduce any characteristics of the satellite itself, but, with a magnitude difference somewhat greater than 2, and assumed albedo and density similar to those for the planet, the diameter of the satellite would be around 0.4 that of Pluto and the mass would be 0.05–0.10 that of Pluto.

^{*}The first orientation predicts transits and occultations in the years 1983–1987, the second in the years 1968–1972.

The satellitelike nature of Pluto lends support to the idea that Pluto may be an escaped satellite of Neptune. Recent calculations by Harrington and Van Flandern (1978) suggest that an encounter by Neptune with a large planet could have ejected a satellite into an orbit that could have subsequently locked into the present resonant orbit of Pluto. The same violent event may also have broken a piece off of the escaping satellite that then became a secondary satellite. A further consequence would be a somewhat irregular planet, with a brightness variation caused by its rotation. Thus, Pluto is certainly not a terrestrial-type planet, and very possibly may not have originally been a planet at all.

A discovery of this nature is not made by one or

two people, but rather is shared in and contributed to by many people. Special thanks go to F.J. Josties, who assisted in examining and checking the original discovery plates; to H.D. Ables and C.C. Dahn, who made the follow-up observations in Flagstaff; to J.A. Graham, who made the follow-up observation at Cerro Tololo; to T.C. Van Flandern, who contributed extensively to the discussion of the interpretation; to all who requested and took the plates that were used in the discovery and confirmation; to S. Jones (Lowell Observatory) and M. Miranian, for photographic help; and to all of the exploratory Development Staff, the Scientific Director and the Superintendent of the U.S. Naval Observatory, for generous support and encouragement.

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