Pluto: Still an Enigma After 50 Years

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ON FEBRUARY 18, 1930, the faint image of Pluto was first seen on a photographic plate by Clyde Tombaugh, a young observing assistant at Lowell Observatory in Arizona. Ever since, Pluto has generally been regarded as the ninth planet of our solar system. Yet only recently have its size and mass been measured with fair accuracy, raising new questions about the object's very nature.

Is Pluto a planet in the fullest sense? Or does it require a reduction in cosmic rank to that of minor planet or moon? Let us review what is now known about Pluto's dynamical and physical properties.

The orbit of this body, although reasonably well known, cannot compare in accuracy with such carefully observed paths as those of the inner planets. The semimajor axis of the ellipse, corresponding to Pluto's average distance from the sun, is about 39.5 astronomical units (a.u.). This is the largest of any known major body in the solar system, and implies a period of approximately 248.5 years.

However, the large orbital eccentricity (0.25) means that Pluto comes as close to the sun as 29.7 a.u. (perihelion distance), somewhat less than Neptune's average distance of 30.1 a.u. Thus, during a small portion of its orbit, Pluto is only the eighth most distant planet from the sun, leaving Neptune the most remote. Such a condition now prevails. Pluto became closer than Neptune during the winter of 1978-79 and will remain closer until the spring of 1999.

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NINTH PLANET DISCOVERED ON EDGE OF SOLAR SYSTEM; FIRST FOUND IN 84 YEARS

LIES FAR BEYOND NEPTUNE

Sighted Jan. 21 After 25 Years' Search Begun by Late Percival Lowell.

SEEN AT FLAGSTAFF, ARIZ.

Observatory Staff There Spots It by Special Photo-Telescope —Makes Thorough Check.

ASTRONOMERS HAIL FINDING

The Sphere, Possibly Larger Than Jupiter and 4,000,000,000 Miles Away, Meets Predictions.

By The Associated Press.

FLAGSTAFF, Ariz., March 13.—In the little cluster of orbs which scampers across the sidereal abyss under the name of the solar system there are, be it known, nine instead of a mere eight, worlds.

New Planet Compared With Earth and Neptune

Size:
Earth—8,000 miles in diameter.
Neptune—32,000.
New Planet—8,000 or more.
Distance from Sun:
Earth—One astronomical unit.
Neptune—Thirty astronomical units.
New Planet—About fifty units.
Speed of Revolution:
Earth—19 miles a second.
Neptune—3½ miles a second.
New Planet—From 1 to 2 miles a second.
Time of Revolution:
Earth—One year.
Neptune—146 Earth-years (entire revolution not yet observed).
New Planet—Probably 300 to 600 years.

Note—These figures on the new planet are tentative, based upon computations of astronomers here on the Flagstaff announcement.

M'DONALD RALLIES NAVAL CONFERENCE

Prime Minister Devotes Whole Day to Talks With Heads of

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Chicago Athletic Dire
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DRY MEMBER ASSAIL

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Special to The New York
WASHINGTON, March 1
Alonzo Stagg, veteran di
athletics at the University
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Judiciary Committee toda
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under national prohibition.
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dry witnesses at today's he
the various modification bill
the committee:
"In my judgment, since p
has been put into effect, hu
thousands more children ha
fairer start in life than e
pre-prohibition days. With t

The *New York Times* front-page Pluto story on March 14, 1930.

Besides the high eccentricity, Pluto's orbit is also the most highly inclined among those of the principal planets. In fact, Pluto's orbital plane forms an angle of more than 17° with the average plane of the solar system, called the invariable plane. Pluto can reach more than 14 a.u. below this plane at its farthest point.

Pluto was crossing to the north side of the plane and was well beyond Neptune on January 21, 1930, when Tombaugh's first discovery plate was taken. Here we see another important consequence of Pluto's high inclination. When the planet passes within the orbit of Neptune it is more than 8 a.u. above that orbit. This condition is likely to last, and to have lasted, for a very long time. Pluto is in no danger of bumping into Neptune, nor was it ever precariously close to that planet in the recent past.

THE MASS-DIAMETER PUZZLE

The prediscovery predictions of a trans-Neptunian planet, based on small unexplained perturbations in the motions of Uranus and Neptune, gave a rather large mass. Percival Lowell assigned his "planet X" a mass seven times that of the earth. W. H. Pickering estimated the mass of his "planet O" as twice that of the earth. The apparent faintness of the planet actually discovered indicated one or more of the following: (1) low reflectivity of its surface material, (2) unusually great limb darkening, (3) very small diameter. The last possibility implied a density seven times that of the earth!

The first real progress addressing these questions came in 1950 and 1951. Using the just-completed 200-inch Hale reflector on Palomar Mountain, Gerard P. Kuiper believed he had measured the diameter of Pluto as approximately 6,000 kilometers. The following year, W. J. Eckert, D. Brouwer, and G. M. Clemence conducted the first dynamical simulation of the outer solar system using a digital computer, which entailed first determining the masses of the five planets involved. Attempting to detect the effects of Pluto on the other planets, particularly Uranus and Neptune, they estimated a mass of about 1.1 times that of the earth. Kuiper's value of the

Clyde W. Tombaugh, discoverer of Pluto, lives in Masilla Park, New Mexico. In this New Mexico State University photograph by Jack Diven, he stands beside the eyepiece of the huge scaffold-mounted 16-inch reflector in his backyard. On March 13, 1980, Dr. Tombaugh was honored at ceremonies in the same Flagstaff, Arizona, auditorium where the first public announcement of the discovery was made exactly 50 years earlier.

diameter thus indicated a density of approximately 60 times that of water, the earth's mean density being only 5.5 on the same scale. This is several times the density of pure iron and therefore much too high.

Further progress came on April 28, 1965, when Pluto *almost* occulted a faint star. The fact that it did not hide the star for any observer, combined with the known apparent closest angular distance, gave an upper limit to the diameter of approximately 5,500 km — not inconsistent with Kuiper's value.

Soon thereafter a major effort was undertaken by the U. S. Naval Observatory to redetermine the mass of Pluto, again using the observed effects on Uranus and Neptune, which by now had been followed more accurately and for a longer period of time. In 1968 an estimated mass of just under 0.2 that of the earth was published, followed in 1971 by an even better value of just over 0.1. This last mass suggested a planet just 40-percent denser than the earth — an unpleasant but tolerable situation.

Only recently have the mass-diameter questions been resolved, with somewhat surprising results. First, it was discovered that the spectrum of sunlight reflected by Pluto has features apparently caused by frozen methane. This implies a rather high albedo and a much smaller diameter than had previously been assumed. Speckle interferometry has now confirmed this result. The diameter of Pluto falls in the range between 3,000 and 3,500 km.

ENTER CHARON

Then two years ago, James W. Christy of the Naval Observatory discovered what appears to be a small Plutonian moon, provisionally named Charon (see SKY AND TELESCOPE for September, 1978, page 211). This find holds promise for unlocking many of the mysteries surrounding Pluto. A satellite affords a direct probe of the gravitational field of the system, making possible a very precise determination of the combined mass of the planet and satellite using Kepler's third law. Charon revolves at a distance of about 20,000 km in a period of 6.39 days. Thus, the mass of the planet is approximately 0.002 that of the earth, or a quarter that of our moon. The new diameter and mass determinations establish a density much less than that of the earth, somewhere between 1.0 and 0.6 times that of water.

One more surprising fact about this planet contributes to the enigma. Most planets are fairly constant in brightness, with observed changes due only to the varying distance of the planet from the earth and sun. However, Pluto has an intrinsic fluctuation, first noted by R. H. Hardie in 1955, of approximately 20 percent over a period of 6.39 days. This light variation is not as simple as that in an eclipsing binary star system, because it increases slowly and falls off more rapidly. Nevertheless, it is generally assumed that this variation is caused by Pluto's rotation, and that the planet must have a rather irregular and somewhat exotic distribution of light and dark patches, possibly on the sides of elevations or depressions.

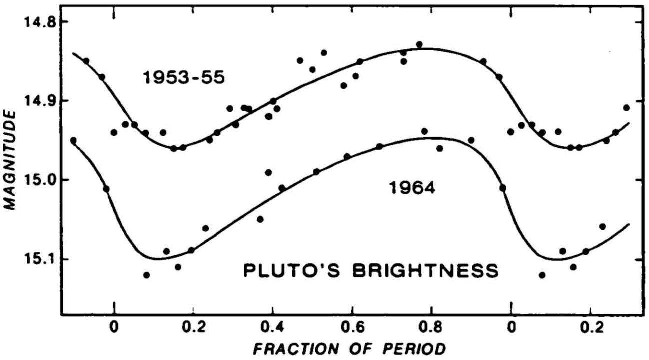
The amount of this light variation has been increasing in the quarter century since first detected, suggesting a gradually changing aspect of the planet as it revolves around the sun. For this to be the reason, the axis of rotation would have to be decidedly nonperpendicular to the plane of revolution.

Again, the discovery of Charon has shed some light on this question. The period of revolution of the satellite is precisely the same as that of the light variation, and the plane of revolution is tilted about 65° to the plane of Pluto's orbit. Actually, the satellite is revolving in a retrograde sense (that is, clockwise around Pluto as seen from the north ecliptic pole), so the inclination is technically called 115°.

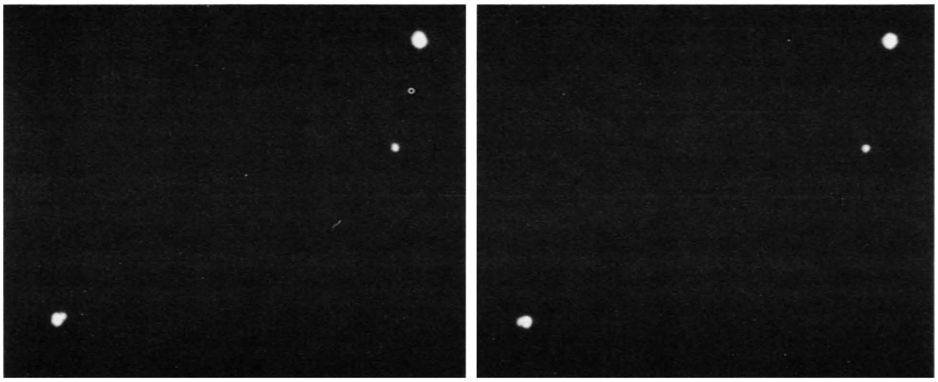
The diagram on page 454 shows the orbit of the satellite with respect to the plane of the sky in 1978, along with the direction of motion of Pluto. Notice that the motion is almost pole-forward in the orbit now, and that we are about to pass through the orbit plane of the satellite, making eclipses and occultations possible in another few years.

Although the satellite period is identical to the light period, Charon is much too faint to account for the light variation. Hence, we have satellite revolution and planet rotation of exactly the same period. And since the poles of most satellite orbits are roughly aligned with the planet's rotational axis, it is probably safe to assume (indeed, this is the only dynamically plausible assumption) that we have in Pluto a situation of complete synchronism. The satellite revolves around the planet in a circular orbit in the plane of the planet's equator, in the same direction as the rotation and with the same period.

Presumably the same things hold true for the rotation of the satellite, but there is no way of knowing this at present. Charon seems to be fixed over a particular



Pluto's six-day brightness variation, found in 1953-55, was noticeably larger as early as 1964. The vertical differences between the two curves are due to calibration uncertainties. Diagram by Robert Hardie.



English amateur Ron Arbour of Bishopstoke, Hampshire, used his recently completed 16-inch f/5 reflector on the night of April 6-7, 1980, to record Pluto's extremely close passage by a 12th-magnitude star. The blended images of planet and star are in the lower left of these 30- and 60-second exposures, made at 22:40 and 0:46 Universal time on Tri-X film. During the 126-minute interval, Pluto moved 8.4 seconds of arc and clearly went just south (above) the star. The three stars in these frames all appear on the chart on page 310 of the April issue; see also the editorial note below.

point on the surface of Pluto, although changing with respect to the stars as the planet rotates and the satellite revolves. This certainly must produce a fixed tidal distortion within the solid body of Pluto itself.

Very little is known about the surface composition of the planet. Traditionally such knowledge comes from analyzing the spectrum and polarization of reflected sunlight, but these are extremely difficult measurements for a planet so faint. Pluto does resemble frozen methane, a result consistent with its density, but there are also some indications of silicates, a component of terrestrial rocks. This would suggest some solid material in the planet, a fact somewhat harder to reconcile with the density. Indeed, there are as many detailed models of Pluto as there are investigators in the field.

Prior to 1978 Pluto was characterized as a dense, dark, terrestrial planet that had somehow gotten into the outer reaches of the solar system. Now we picture a relatively small, low-density methane snowball, with possibly ammonia and other impurities. The highly reflective but rather irregular surface has dark spots, possibly representing depressions. Over one hemisphere of the planet hangs a stationary satellite, quite impressive in size (about 4½° across compared to ½° for Earth's moon), but rather dimly lit by the distant sun.

QUESTIONS

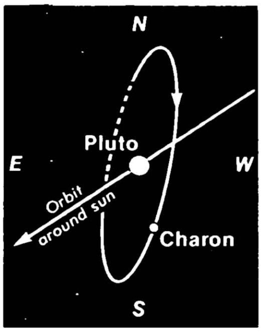
What is this strange object Pluto? Perhaps it should remain within the ranks of so-called "principal planets" in the solar system, albeit by far the smallest and possessing the most anomalous orbit. However, demotion to "minor planet" may be in order. This would make Pluto the largest and by far the most distant asteroid.

It has been suggested that Pluto lies at the true edge of the solar system and is only one of many bodies that formed around the rim of the primordial solar nebula as it began its collapse. Indeed, in this sense, Pluto fits in well with the low-density comets. Is it a supersize comet nucleus?

In terms of size, mass, and density, Pluto closely resembles the intermediate-size satellites of Saturn, suggesting an origin as a moon of some principal planet. The most obvious parental candidate is Neptune, especially considering the peculiar satellite system that Neptune now has. Triton, its large satellite, is the only one in the solar system that is both retrograde and tightly bound. Nereid, its small satellite, has the highest known eccentricity apart from the comets. Perhaps this family of moons was once quite normal and orderly, and included Pluto. Some cataclysmic event could have deranged them, such as an encounter with a yet-to-be-discovered planet thrown into the outer reaches of the solar system by the same encounter. The argument that Neptune and Pluto do not now come close says nothing about them in the distant past, when forces now negligible may have been at work evolving the solar system.

ORBITAL AND PHYSICAL CHARACTERISTICS

	Earth-Moon System	*Pluto-Charon System*
Separation	384,000 km	20,000 km
Revolution period	27.32 days	6.39 days
Planet		
Mass (Earth = 1)	1.0000	0.0023
Diameter	12,750 km	~3,000 km
Density (water = 1)	5.5	~1
Rotation period	1.00 day	6.39 days
Satellite		
Mass (Earth = 1)	0.0122	0.0002
Diameter	3,480 km	~1,300 km
Density (water = 1)	3.3	~1?
Rotation period	27.32 days	6.39 days?
Planet/sat. mass ratio	81.3	~10



Charon has not yet been clearly seen, but this Naval Observatory diagram shows the most likely aspect of its orbit.

In any case, Pluto is obviously not Lowell's planet X nor Pickering's planet O, or any of the other planets that have been hypothesized to explain the discrepancies between the observed and predicted motions of Uranus and Neptune.

These lingering discrepancies may be nothing more than artifacts of the procedures originally used to process the early observations. Or the dynamical explanation may yet prove to be the correct one. If, in its necessarily highly elliptical orbit, the still-missing planet were close enough to the inner solar system to affect Uranus and Neptune 200 years ago, it should return a few centuries hence to cause disturbances again. In the meantime, it must be wandering around in the very outer reaches of the system, disturbing nothing more than the comets and the peace of mind of astronomers.

Yet today, more than ever, Pluto seems an apt name for the lesser object we have been considering. That mythological character, associated with the mysterious underworld, seems at home with the pattern of knowns and unknowns surrounding the planet that bears his name.

EDITOR'S NOTE: As this issue goes to press, an important new observation is being studied. On April 6th, the 12th-magnitude star in the photographs above actually disappeared for 50 seconds centered on 23h 39m 28s Universal time, as recorded photoelectrically in South Africa. Alistair R. Walker was using the 1-meter telescope of the South African Astronomical Observatory in Sutherland, 170 miles northeast of Cape Town.

In announcing this observation, IAU *Circular* 3466 of April 10th commented, "The event was apparently caused by Pluto's probable satellite . . . which is deduced therefore to have a minimum diameter of 1,200 km."

On April 25th, R. S. Harrington telephoned SKY AND TELESCOPE with the news that Naval Observatory astrometric plates taken April 13th and 20th suggest the star was approximately 1.0 second of arc north-northwest of Pluto itself at the time of the occultation, not far from the predicted location of Charon. This supports the conclusion that Charon was the occulting body, but remaining uncertainties will not permit much improvement in the satellite's orbit and diameter as presented in his table at left.