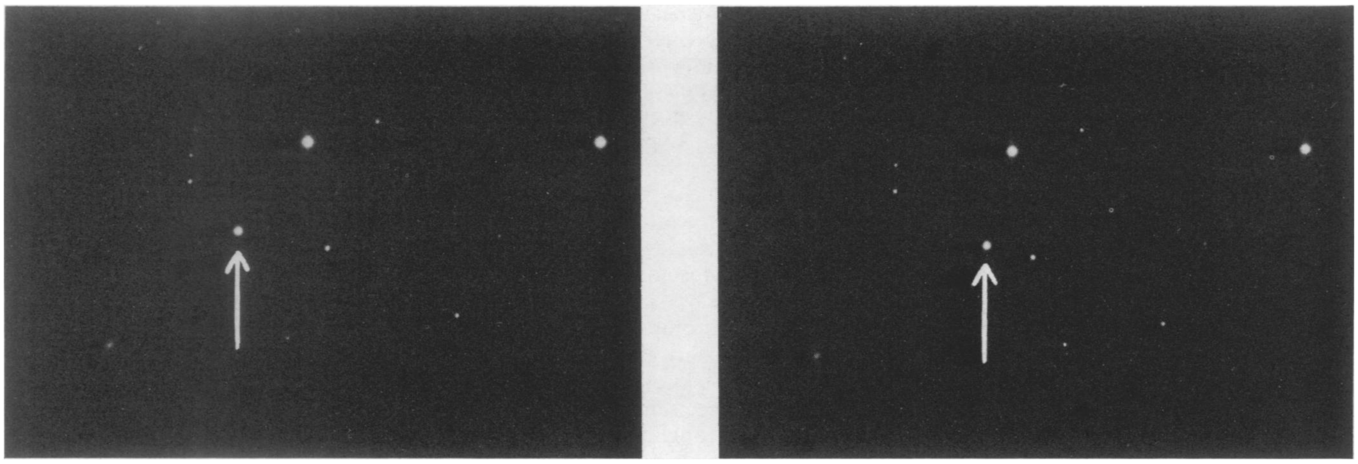


Hale Observatories

The great distance and small size of Pluto make study difficult. Observations 24 hours apart show its motion.

The shrinking mass of Pluto

As calculations of Pluto's mass become more refined, the farthest planet becomes lighter and lighter

by Dietrick E. Thomsen

Pluto was the last of the planets to be discovered (in 1930). If astronomers continue to make it lighter, it may be the first to disappear.

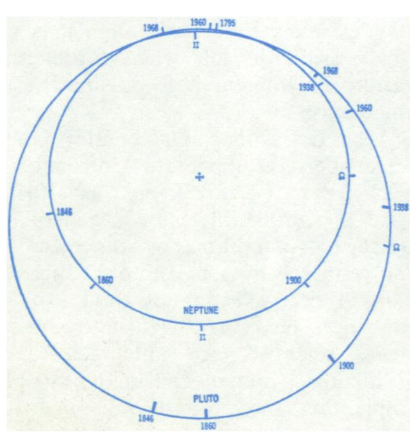
A calculation by Dr. L. R. Wylie in 1942 gave Pluto a mass equal to 0.91 of the earth's mass, or, as celestial mechanicians usually put it, a reciprocal mass of 360,000. (Reciprocal mass is the number of times the planet's mass must be multiplied to equal the sun's mass; a reciprocal mass of 360,000 means that the planet's mass is 1/360,000 of the sun's.)

In 1955 Dr. Dirk Brouwer made Pluto's mass out to be 0.82 of the earth. A recalculation in 1968 by Drs. R. L. Duncombe, W. J. Klepczynski and P. K. Seidelmann of the U.S. Naval Observatory represented a real comedown, to 0.18 of the earth's mass. The last step so far was made by Drs. Seidelmann, Klepczynski, Duncombe and E. S. Jackson and published in the June Astronomical Journal. It brings Pluto down to 0.11 of the earth's mass, less than an eighth of its former self. In reciprocal mass the change is from 360,000 to 3 million.

One reason for all this revisionism is that the older figures gave Pluto a fantastic density. Observation so far indicates that Pluto's diameter is no more than 6,400 kilometers. At this size the older mass figures yield a density of about 40 grams per cubic centimeter. The earth's density is only 5.5. A Pluto made of solid uranium, the densest element, would be only 18.95. The latest mass figure gives Pluto a density of 4.85, a value that seems far more plausible to planetary scientists.

The wide discrepancies among the figures presented for the mass of Pluto illustrate the particular difficulties of measuring its mass. The mass of a planet is determined from the planet's effects on the motion of other celestial bodies: satellites, comets, asteroids, other planets, and nowadays sometimes space probes.

If a planet has satellites, its mass can be determined from studying their motions. The case is especially nice if the satellite masses are negligible compared with the mass of the planet. (Some indication of this is given by the accuracy of the tabulated figures for Jupiter and Saturn compared with those for the others.) But Pluto has no known satellites.



Duncombe, et al./Science

Pluto is now inside Neptune's orbit.

If a planet has no satellites, astronomers can wait until a comet or an asteroid comes near and study its motion. Such events have happened now and then to the inner planets, which have been observed for centuries, but Pluto has been under observation for only 40 years.

For Pluto the only possibility so far is to use its effect on the motions of other planets. The fundamental difficulty with this method is that by far the dominant influence on a planet's motion is the sun. The effects of other planets are only small perturbations and difficult to sort out mathematically.

Pluto's largest perturbation interaction is with its nearest neighbor, Neptune. Pluto comes quite close to Neptune at times—in fact a portion of Pluto's orbit lies inside Neptune's, a circumstance that has led some astronomers to suggest that Pluto is an escaped satellite of Neptune. Most of the mass determinations of Pluto come from studies of Neptune's motion.

The way it is done is exemplified by the procedure Drs. Duncombe, Klepczynski and Seidelmann used in their 1968 calculation. They took observed positions of Neptune from the early part of the period during which that planet has been observed and calculated several orbits for Neptune using a different hypothetical Pluto mass in each.

They then checked observed positions of Neptune made later than the ones used in the calculation to see which of the calculated orbits fit them best. That orbit gave them the best mass of Pluto. (In the course of this they found that the orbits of Neptune on which the earlier determinations of Pluto's mass were based did not accord well with the positions Neptune has occupied since those orbit calculations.)

A major difficulty involved with using Neptune's motion is that since 1846, when Neptune was identified as a planet, it has completed only about three-quarters of one orbit. With this limit on observation, it is easier to make mistakes predicting Neptune's orbit than it is in predicting the orbit of a planet for which one or more full orbits are on record.

Since 1968, Drs. Klepczynski, Seidelmann and Duncombe have been working on new determinations of the masses of the other outer planets, Saturn, Uranus and Neptune. As a result of these new determinations, a new calculation for Pluto was necessary. It is the one that yielded the latest figure.

In this age of astronautics, accurate values for planetary masses are important not only for the precision of the ephemerides by which terrestrial navigators find their way around, but also for the navigation of spacecraft. A small discrepancy in the mass of a planet can mean a large deviation in the motion of a space probe that flies near it.

Drs. Klepczynski, Seidelmann and Duncombe have therefore recalculated the masses of all the planets using the best independent observations they could find. They presented the results to the 17th Annual Meeting of the American Astronautical Society in Seattle in June. They suggest certain changes in the currently accepted values. For the innermost planets, the alterations are slight. For outer planets they are more significant. For Pluto the change is drastic.

All this reflects the fact that the more observations of a planet there are, the more likely they are to agree. As the centuries go by and Pluto is more observed, presumably the data about it will begin to converge. Pluto is not likely to disappear, but it is likely to remain a lightweight. □

MASSES OF THE PLANETS

Planet	Reciprocal Mass: standard value	Reciprocal Mass: value suggested by Klepczynski, *et al.*	Fraction of earth mass based on suggested value
Mercury	6,000,000	5,987,000 ± 31,000	0.56
Venus	408,000	408,519 ± 11	0.77
Earth & Moon	329,390	328,900.12 ± 0.20	1.01
Mars	3,093,500	3,098,709 ± 9	0.11
Jupiter	1,047.355	1,047.364 ± 0.006	315.15
Saturn	3,501.6	3,498.1 ± 0.4	94.38
Uranus	22,869	22,755 ± 89	14.52
Neptune	19,314	19,325 ± 26	17.05
Pluto	360,000	3,000,000 ± 500,000	0.11

The sun's mass is about 1.99×10^{27} metric tons; the earth's is about 5.98×10^{21} metric tons.

INVESTIGATIONS OF THE MASS OF PLUTO

Number	Reciprocal Mass	Author	Year	Object
1	330 000	Jackson	1930	Neptune (1795-1928)
2	>3000 000	Bower	1931	Brightness
3	350 000	Nicholson, Mayall	1931	Neptune (1795-1930)
4	> 660 000	Brown	1931	Uranus (1780-1900)
5	330 000	Wylie	1942	Neptune (1795-1938)
6	350 000	Kourganoff	1944	Neptune
7	930 000	Eckert, Brouwer, Clemence	1951	Uranus (1781-1938)
8	400 000	Brouwer	1955	Uranus & Neptune (1712-1941)
9	450 000	Brouwer	1955	Longitudes only of Uranus & Neptune (1712-1941)
10	1812 000	Duncombe, Klepczynski, Seidelmann	1968	Neptune (1795-1968)
11	3000 000	Seidelmann, Klepczynski, Duncombe	1971	Neptune (1846-1968)