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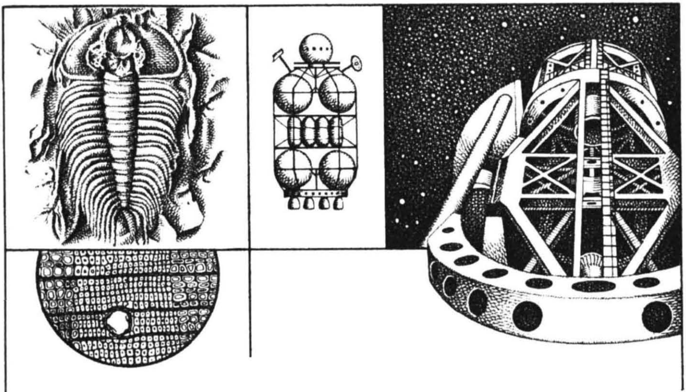

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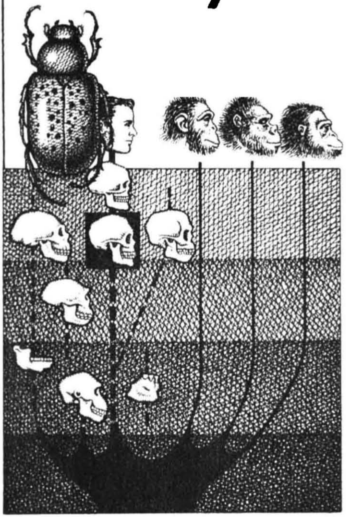
By WILLY LEY



THE DEMOTION OF PLUTO

PLUTO, outermost known planet of the Solar System, is, of course, still technically a planet, since it moves around the Sun in a closed orbit. But it is now being said that Pluto did not always have full planetary status. It has been charged—by Dr. Gerard Peter Kuiper of the University of Chicago — with being a "runaway moon" of Neptune.

I can't make up my mind at the moment whether the charge that it is a former moon that managed to make itself independent should be considered detrimental to its reputation or whether that should enhance it. But if you take the position that being a runaway moon instead of a born planet is a demotion, you may also add that the demotion is richly deserved. Pluto simply failed to live up to the advance publicity it received as "Planet X" before its discovery. It has been a disappointment all along, for it did not turn out to be what one could reasonably have expected.

Seriously: the proper status of Pluto became dubious quite soon after the general jubilation following its discovery by Clyde W. Tombaugh in 1930. Questions piled up quickly. Was it really the Planet X for which Percival Lowell had instituted a search? Did it really cause the gravitational effects from which its presence and orbit had been calculated?

And was its final discovery, after years of diligent and difficult search, possibly just due to a lucky accident? Was it possible that Planet X, predicted not only by Percival Lowell but by other astronomers as well, still remained completely unknown and yet to be discovered?

FOR an astronomer to hunt one celestial body and discover another is not as incredible as it may sound. One of the minor moons of Jupiter was found in just that way. And it has happened repeatedly that an astronomer "checked" on one asteroid only to find out, after a while, that he had actually discovered a new one.

That such things do not happen only in the crowded Asteroid Belt is shown by a famous case involving a transatlantic cablegram. In Europe, they had discovered a new comet—not a very rare event if you have telescopic comets in mind. The observatory which made the discovery wanted it verified and cabled the fact of the discovery and the position of the object to the Lick Observatory.

The telegraph operator, obviously ignorant of astronomical notations, garbled the figures. Lick Observatory, of course, accepted the figures that had been received, and when this particular area of the sky became observable, they looked. Quite close to the cabled position, a telescopic comet was found.

It was a new comet—not the one the Lick astronomers had been asked to verify!

It has become customary to say that the discovery of Pluto began with the discovery of Uranus by Sir William Herschel on March 13, 1781. While this statement can be maintained on the grounds that the discovery of Uranus showed that there were planets beyond Saturn, which had been accepted as the outermost planet for so many centuries, there were actually many differences.

When Herschel found Uranus, he had not been looking for a new planet. There was no suspicion that it might exist, no theoretical reasoning assuming its existence. Herschel simply found it and, as a matter of fact, he believed for some time that he had merely discovered a new comet. After it had been established as a planet, it was located on quite a number of earlier star charts—17 in all — where unsuspecting observers had entered it as a fixed star.

Using these older chance observations and, of course, all the observations since the discovery by Herschel, Alexis Bouvard in Paris constructed tables of the motions of Jupiter, Saturn and Uranus. As far as Jupiter and Saturn were concerned, the tables and the observed positions agreed nicely. For Uranus, they did not agree.

One way out of the difficulty was to assume that the older observations had been careless — although there was no reason for such a posthumous insult to able observers — and to discard them. Then new tables were calculated, based only on observations after Herschel's discovery.

A few years later, it became unmistakably clear that these tables did not work, either. And in 1834, an amateur astronomer, the Reverend T. J. Hussey, wrote a letter to Sir George B. Airy, in which he blamed an unknown planet outside the orbit of Uranus for the discrepancy between calculation and observation.

THE view that an unknown planet might explain much became common among astronomers fairly fast. Professor F. B. G. Nicolai, then director of the observatory at Mannheim, said that this would best explain the fact Halley's Comet did not behave precisely as calculated. This was in 1835.

In 1842, Friedrich Wilhelm Bessel, during a visit to Sir John Herschel, the son of the discoverer of Uranus, declared that he was convinced that there was an unknown planet. After his return to Germany, he assigned his assistant to the task of calculating the position of an unknown planet from the observed discrepancies. But by that time, Bessel was no longer a young man; he died in 1846 and the job remained unfinished, at least as far as Bessel's discovery in Konigsberg is concerned.

But it had been completed just during those last few years of Bessel's life in two other places.

In France, Urbain J. J. Leverrier presented his report on the calculation of the existence and position of a Trans-Uranian planet to the French Academy on November 10, 1845.

In England, John Couch Adams, a rather young man who had only recently received his bachelor's degree, did the same work and forwarded his report to Sir George B. Airy around November 1st, 1845.

There has been much unnecessary discussion on whether priority should be awarded to Adams or to Leverrier. The plain fact is that both men did the same work at the same time. Since astronomical circles were well acquainted with the "misbehavior" of Uranus, it is surprising that more people were not attacking the same problem simultaneously.

IT MAY be worthwhile to pause for a moment here and explain just what it was that made astronomers speak in such decided terms about an "unknown planet." Let us first consider the case of a single planet moving around a sun. To simplify the picture still more, let us assume that its orbit is not a ellipse, as it very likely would be, but a circle. In this case, the single planet would move at a constant rate; it would arrive at a certain point at a specific time. Now we add a second planet, which moves around the same sun, but in an orbit outside the orbit of the first planet. It will move at a slower rate and it also has to follow a much larger path.

The result is that the inner planet will overtake the outer one at regular intervals. As the two come near each other, the effects of their own gravitational fields will enter into the game. They pull each other, and the inner planet moves a bit faster than it would if the other did not exist. By the same token, the outer planet is slowed down a bit. The closer they come to each other, the more strongly this mutual "perturbation" will show up.

But at the instant the inner planet passes the outer planet, the effect is reversed. Now the inner planet is slowed down by the pull of the outer one, which falls behind, while the outer planet is speeded up a bit by the attraction of the inner one that races ahead.

In short, if a planet, at a certain point of its orbit, first speeds up and then slows down, it indicates a gravitational pull by a body in an orbit farther away from its sun. Conversely, a slowing down followed by a speed-up would indicate the presence of another body in an orbit nearer its sun.

To return to the case of Uranus, it was slowed down a little and then suddenly pulled along by the gravitational fields of both Saturn and Jupiter. Their orbit, positions and weights were known and could be taken into account. But even when all the perturbations by Saturn and Jupiter had been figured in, calculations and observations obstinately failed to agree.

Of course observers make minor mistakes, but not all observers make them in the same direction. Moreover, the discrepancies were too large to be ascribed to "observational errors." And the whole picture suggested a pull from "outside." If astronomers had observed Uranus for several complete revolutions around the Sun, they could have established the period of the unknown planet outside of Uranus simply by tabulating the interval between two such perturbations that could not be ascribed to Saturn or to Jupiter.

If they are so-and-so-many years apart, then the period of revolution of the external unknown body must be so-and-so-many years. It would have been simple.

BUT Uranus needs 84 years to go around the Sun once. In 1845, it had not been observed for even one complete revolution. You could stretch that by taking the older observations, where the planet had been mistakenly entered on star charts as a star, but even then the evidence was spotty and the calculation far from simple. To get anywhere, one assumption had to be made, concerning the distance of the unknown planet from the Sun.

John Couch Adams assumed a distance of 38.4 A. U. (astronomical units) — he expected the unknown planet to be 38.4 times as far from the Sun as the Earth revolves around it. That assumption was according to the Bode-Titius rule (see Table I) which succeeds in expressing the distances of the planets from the Sun by simple arithmetic. Nobody quite knows why it works that way, even though there has been much thought expended on just that problem.

Even though we don't know why, a glance at the table shows that it does work nicely for all the planets from Mercury to Uranus. There was no reason to assume that it should not work for the unknown planet, too, and Adams began his work by supposing that distance for the unknown body.

As for Leverrier in France, he assumed a distance of 36.15 A.U. With either assumption, a case for an unknown planet could be worked out and both Adams and Leverrier could say that the planet should be in a given position along its orbit on a certain day.

Adams picked October 1st, 1846, as the day for which he made his calculation and stated that it should be in heliocentric longitude 328° or 329°. (The true position of Neptune for that day was 327°57′.) Leverrier picked January 1st, 1847, as his date and gave a heliocentric longitude of 326°32′ as the probable position of the unknown planet. The two independent calculations agreed rather well, as one can see.

THE next problem was, naturally, to find it in the sky. This meant searching the area of the calculated position more or less around the plane of the ecliptic, since all the planets of the Sun move in about the same plane as does the Earth.

If this had to be done today, the observer would photograph that region of the sky, wait three days or so and photograph the same region again. Then he would settle down to the job of comparing the plates in order to see whether one of the dots of light had moved during the time elapsed between exposures. There is a special instrument for doing just that, but even with this instrument, it is tedious work. Moreover, a few known planets might move in the same area and have to be identified first.

But in 1846, photography was not yet a help to the astronomer and the job had to be done visually. The area of the sky had to be compared with prepared star charts to see whether an unmapped dot of light had wandered in.

TABLE I — The Bode-Titius Rule

4+(0×3) : 10=	0.4;	MERCURY,	actual distance	0.39 A.U.
4+(1×3) : 10=	0.7;	VENUS,	" "	0.72 A.U.
4+(2×3) : 10=	1.0;	EARTH,	" "	1.00 A.U.
4+(4×3) : 10=	1.6;	MARS,	" "	1.52 A.U.
4+(8×3) : 10=	2.8;	CERES,	" "	2.77 A.U.
4+(16×3) : 10=	5.2;	JUPITER,	" "	5.20 A.U.
4+(32×3) : 10=	10.0;	SATURN,	" "	9.54 A.U.
4+(64×3) : 10=	19.6;	URANUS,	" "	19.19 A.U.
4+(128×3) : 10=	38.8;	NEPTUNE,	" "	30.07 A.U.
4+(256×3) : 10=	77.2;	not matched by a known planet		
4+(512×3) : 10=	154.0;	also not matched		

It is now known that the British observer entrusted with the search by Airy actually saw Neptune, but failed to pay attention to it. His whole performance was such that it is safe to say that he wasn't interested in the project and merely went through the motions he had been ordered to make.

Leverrier, in September, 1846, wrote to the German astronomer Galle in Berlin, who requested the permission of the director of the observatory, J. F. Encke, to proceed with the search. Encke approved and Galle, assisted by a student named H. L. d'Arrest, went to work. He found it the same night and verified the discovery during the following night.

Much later, it turned out that the French astronomer Lalande had seen the planet twice, on the 8th and 10th of May, 1795. But since the "star" seemed to have shifted positions, Lalande concluded that he must have made a mistake in one of his observations. The position which seemed less likely to him, for reasons we don't know, he rejected completely. The other one he decorated with a question mark and let it go at that!

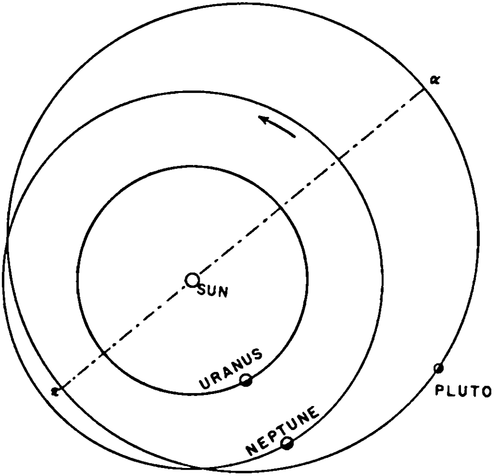
After Neptune had been discovered, it was only natural that virtually everybody wondered whether the story would be repeated. Of course first it was necessary to learn everything that could be learned about Neptune.

Almost at once, its large moon Triton was discovered—by William Lassell — and it was established that it was 220,000 miles from the planet, that its diameter must be around 3000 miles and that it needed 5.88 days to go once around Neptune.

As for Neptune itself, it was slightly larger than Uranus, with a diameter of 33,900 miles (that of Uranus 30,900 miles) and that it turned around its axis at a rather fast rate, in 15 hours and 40 minutes. (Uranus does it in 10 hours and 40 minutes.) Neptune was not only slightly larger than Uranus but also heavier — it would take 14.7 Earths to balance Uranus on a scale; for Neptune, 17.2 Earths would be needed.

I may add here, out of chronology, that Gerard P. Kuiper discovered a much smaller moon of Neptune in 1949. It is small, about 200 miles in diameter, and needs 730 days to go around the planet in a very elongated orbit.

WHILE Neptune compared to Uranus and the other large outer planets in most respects, it proved to be surprising as far as its distance was concerned. It was 8.8 astronomical units closer to

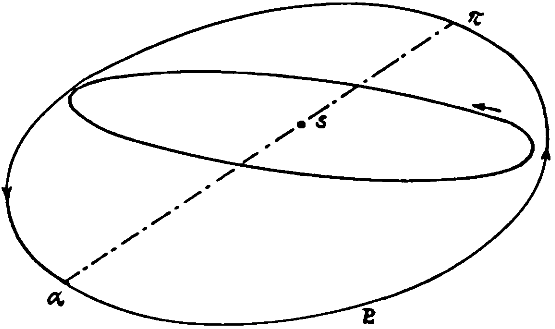


Orbit of Pluto projected on the plane of Neptune's orbit. The Greek letter alpha marks Pluto's aphelion, the letter pi its perihelion

the Sun than the Bode-Titius rule said; it was 820 million miles farther inward in the Solar System than one could reasonably expect.

The main problem was not changed by this fact — whether the Bode-Titius rule missed in the case of Neptune or not, was there a planet still farther out? To derive its presence, provided it existed, from irregularities in the motion of Neptune, would have required a long wait, for Neptune needs almost 165 Earth years for one revolution. But there were other leads one could follow.

Comets, which have very little mass, are very strongly "perturbed" by planets. It was the French astronomer Camille Flammarion who pointed to a comet thus "perturbed" and far outside the orbit of Neptune, at that. More of them were found after Flammarion had put the idea into some minds. Moreover, a planet beyond Neptune, a "Trans-Neptune," would not only

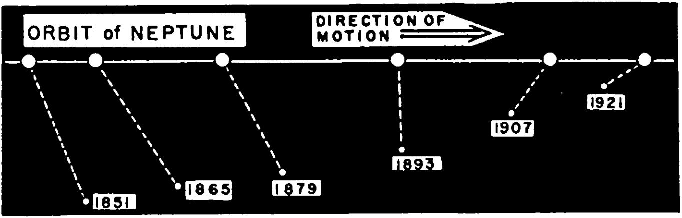


Pluto's orbit drawn in perspective to show that it does not actually cross Neptune's orbit

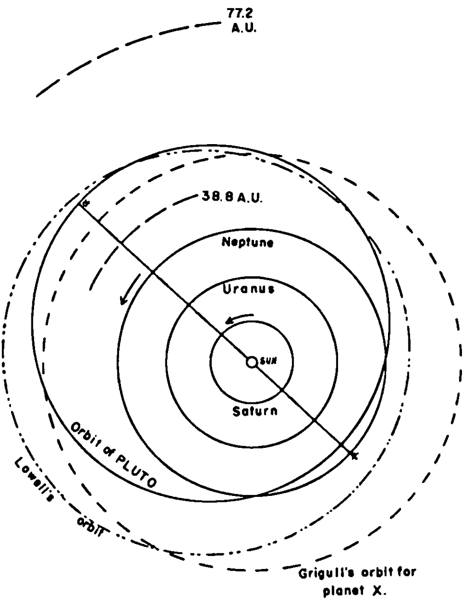
perturb the orbit of Neptune; it would also show up in the motions of Uranus, which by 1900 had been observed for one and a half of its revolutions.

There seemed to be enough evidence by then for Professor George Forbes to predict a Trans-Neptune at a distance of about 100 A. U., requiring 1000 years for one complete revolution. He expected it to be even larger than Jupiter in size!

The German astronomer Dr. Theodor Grigull of Munster supposed a Trans-Neptune which he called "Hades" at a distance of 50 A. U. with a period of revolu-



The relative positions of Neptune and Pluto as seen from the Sun for about 80 years prior to Pluto's discovery



The orbits of the outer planets, actual and predicted. (For explanation, see text)

tion of 360 years and a size like Uranus or Neptune.

Professor William H. Pickering came to a very similar conclusion. His Trans-Neptune was a little farther out than Grigull's, with a period of 373 years.

And Thomas J[efferson] J[ackson] See predicted the planet "Oceanus" at 41.25 A. U. with a period of 272 years. He went further — there probably was a Trans-Oceanus at 56 A. U. with a period of 420 years and still another at 72 A. U. with a period of somewhere around 610 years.

The most careful set of calculations was that of Percival Lowell, published in 1915 under the title *Memoir on a Trans-Neptunian Planet*, which he called "Planet X." He supposed it to be of about half the mass of Uranus, or seven Earth masses, with a period of around 280 years.

One important difference between Lowell and the other astronomers who had thought about the same problem was that he had his own observatory.

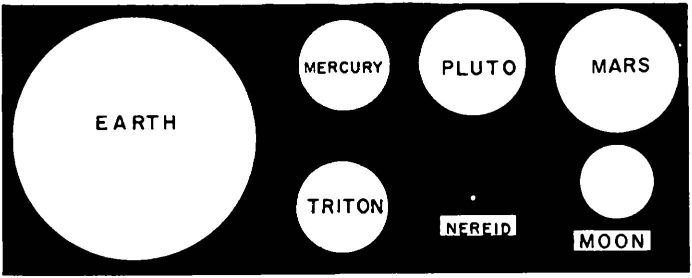
After having reached a theoretical conclusion, he could start an actual search. He did not know, of course, that he was not to live much longer — he died in November, 1916 — but all the time that was left to him, he hoped that one of his assistants would inform him about the actual discovery.

THE announcement came more than 13 years after his death, on March 13, 1930. The date had a double significance— it was both the date on which Herschel had discovered Uranus and Percival Lowell's birthday.

Pluto really was discovered, though, in the afternoon of February 18, 1930, when Clyde W. Tombaugh examined two plates, taken on January 23rd and January 30th, both centered on the star Delta Geminorum. Tombaugh said later that he was sure at once — the two images were as sharp as those of stars (a comet image would have been somewhat diffuse) and the displacement was right for a planet beyond Neptune.

Of the names that had been suggested for Planet X, the name Pluto was chosen, since it began with the letters P.L., the initials of the man who had predicted it. A comparison between the prediction and actuality is given on Table II, but it must be kept in mind that it took years until the figures for Pluto were established and that the values given in the last three lines did not become known until recently.

But the searching questions arose soon. Pluto's orbit, as it became known, was unlike that



The diameters of the three smallest major planets compared to that of Earth, of our moon and the two moons of Neptune. (The diameter of Pluto taken as 45 per cent of that of Earth)

TABLE II	PLANET X	PLUTO
Period	282 years	248.43 years
Perihelion	204.9°	223° 10′ 30″
Inclination	about 10°	17° 8′ 38.4″
Eccentricity	0.202	0.2486438
Distance at perihelion	34.31 A. U.	29.8 A. U.
Same in million miles	3,190	2,770
Distance at aphelion	51.69 A. U.	49.4
Same in million miles	4,808	4,595
Length of major axis of orbit	86 A. U.	78.9 A. U.
Rotation	not predicted	6.4 days
Diameter	not predicted	3,550 miles
Mass compared to Earth	7	less than 5 per cent

Comparison between Lowell's "Planet X" and Pluto

of any other planet. It was strongly inclined to the ecliptic and so eccentric that the planet's perihelion, the point of its orbit nearest the Sun, is actually closer than the nearest Neptune can come to the Sun, even though the average distance is greater. Pluto will go through its perihelion in 1989 and, for the period from 1969 to 2009, it will be closer to the Sun than Neptune. Aphelion, the point farthest from the Sun, will be reached in 2113. An orbit like that just did not sit well with a planet.

The next question was its size. It was too small to show a disk in any telescope then in existence. That meant that it had to be far smaller than Neptune, for even the Earth should still show a tiny disk at that distance.

But if it was smaller than the Earth, say somewhere between Earth and Mars in size, it could not possibly cause a measurable pertubation on planets as large and as distant from it as Uranus and Neptune. To make it cause the perturbations from which Planet X had been computed, its average density would have to be sixty times that of water. Such densities in a planet that size cannot exist.

Then Kuiper succeeded in making some direct measurements. The first figure given, accompanied by the statement that the probable margin of error was large, was a diameter of 6000 miles, 2000 miles less than that of the Earth. The next figure was 3700 miles, less than that of Mars, which is 4200 miles. Meanwhile, this has been revised downward some more, to around 3500 miles, which is the same as the diameter of Saturn's largest moon, Titan.

I DON'T recall who said it first, but about ten years after Pluto's discovery, somebody remarked that it might merely be a runaway moon of Neptune. Pluto seemed to be about as far displaced north and south from the ecliptic as Neptune was "displaced" inward, if you took the Bode-Titius rule seriously. The total picture of the edge of the Solar System looked as if something violent had taken place there at one time.

Neptune was more than 800 million miles closer to the Sun than it should be. Its then only known satellite Triton moved around it in the wrong direction and Uranus seemed to have been influenced to the extent of having its axis as well as the orbits of its satellites tilted by around 90 degrees. Whatever it was that did all this could easily have torn Pluto away from Neptune and thrown it into the orbit it now has.

But nobody could figure out a force which could tilt Uranus by 90 degrees without disturbing its orbit and which could move Neptune by 800 million miles without making its orbit eccentric.

But one more discovery about Pluto makes it more likely than ever that it once was a moon of Neptune. Pluto had to have a period of rotation around its axis. But that period was not known until very recently, when it was found to be 6.39 days.

This is much slower by far than the rotational period of any other of the outer planets. Only moons rotate that slowly around their axes, because all moons are forced by their planets into a period of axial rotation equal to the periods of their revolutions around their planets. If Pluto, when a moon of Neptune, was somewhat farther out than Triton, a period of 6.39 days would be very logical.

Dr. G. P. Kuiper thinks that Pluto made itself independent at a very early stage of the formation of the Solar System. In fact, he believes that at that time Neptune lost Triton and Nereid, too, but later succeeded in recapturing them. At any event, the discovery of the slow axial rotation of Pluto makes it certain that it is not the Planet X Percival Lowell and the others were postulating.

Whether Planet X exists is still uncertain. And where it is, if it exists, is still unknown.

—WILLY LEY