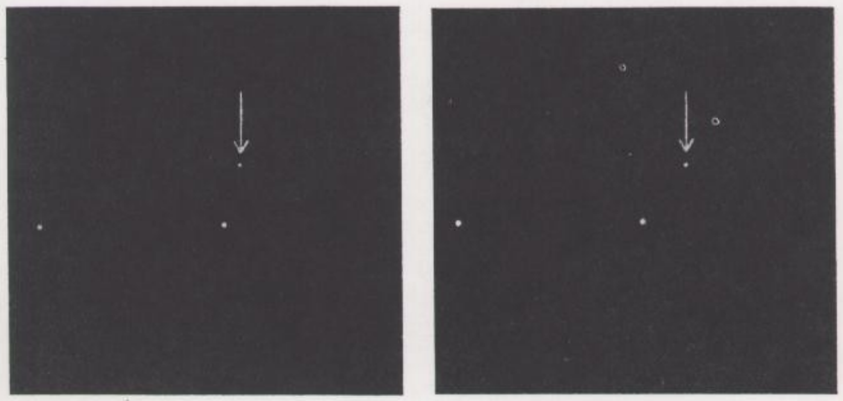
Overview — Brown Dwarf (AKA Planet X) Articles

This category of collected news articles provides evidence of an 'official' search for our Brown Dwarf companion. The headlines read: "Something Lurking Behind the Planets." New Scientist Magazine 1982 and "Does the Sun Have a Binary Companion." Newsweek Magazine 1982.

The following article is an example of News clippings collected for this category:

"A heavenly body possibly as large as the giant planet Jupiter and possibly so close to earth that it would be part of the solar system has been found in the direction of the constellation Orion by an orbiting telescope called the Infrared Astronomical Observatory…The most fascinating explanation of this mystery body, which is so cold [at the moment] it emits no light and has never been seen by optical telescopes on earth…"—*Vancouver Sun 1983*.



Above: Pluto is so small and so far away that even the giant 200-in (508-cm) Hale telescope shows it only as a faint star. These two photographs show Pluto's motion against the background of the stars over 24 hours.

results in the flattening of the polar regions. But this effect is even more marked than with Jupiter; there is a difference of nearly 13,000 km (8000 mi) between the polar and equatorial diameters.

Beyond the Naked Eye

On the fringes of the solar system beyond Saturn are three more planets so distant as to be beyond the normal range of vision. First is Uranus, discovered by William Herschel in 1781; then Neptune, discovered by J. Galle in 1846; and finally Pluto, discovered by Clyde Tombaugh as recently as 1930.

Uranus is classed as a giant planet, too, with a diameter nearly four times that of Earth. It is much smaller than Jupiter and Saturn, but it is very much like these planets in many ways. It is primarily a gaseous body of low density covered with a thick atmosphere of hydrogen and methane. No ammonia is present, which is to be expected at the very low temperatures existing there (−200°C). Uranus also rotates rapidly on its axis and is markedly flattened at the poles. Its internal structure is believed to be much like that of Jupiter and Saturn.

The planet can be seen with binoculars, but scarcely ever with the naked eye. This is not surprising, since it lies twice as far away from us as Saturn. Even with a powerful telescope Uranus appears as little more than a greenish-yellow disc, with vague markings that could be cloud belts.

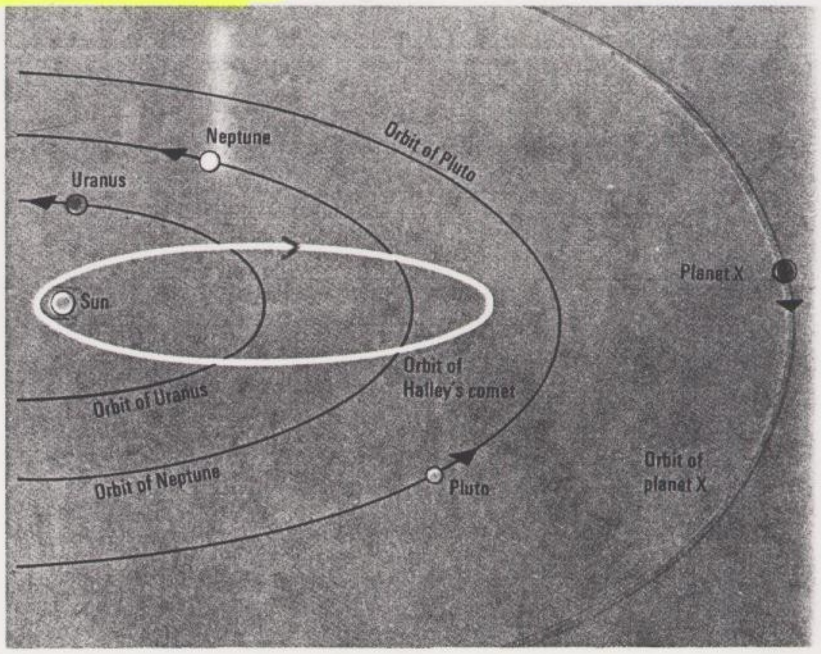
The most remarkable feature of Uranus is the enormous tilt of its axis (98°). As a result of this tilt, the planet's axial rotation is effectively retrograde, and so are the motions of its five satellites – Miranda, Ariel, Umbriel, Titania and Oberon – none of which exceeds 1000 km (620 mi) in diameter.

Neptune is a near-twin of Uranus, being almost identical in size and in constitution. (Neptune is in fact fractionally bigger, with a diameter 1200 km (745 mi) greater.) Being much farther out than Uranus, Neptune can never be seen with the naked eye, and even a telescope will show no details on its disc. It is several degrees colder than Uranus. The planet has two satellites. Triton is nearly as large as Mercury, and has a retrograde circular orbit relatively close to the planet. Nereid is only about 250 km (150 mi) across, and its orbit is distant and highly eccentric.

The farthest known planet, Pluto, differs in every respect from its planetary neighbours. It is a very small body, only a little bigger than Mercury. It is though to be made up of rock, overlain with frozen gas. It rotates very slowly – once in every 6 days or so.

On average Pluto lies nearly 600 million km (3700 million mi) from the Sun. But its orbit is unusually eccentric. Periodically, Pluto travels *inside* the orbit of Neptune; it is doing so at present. The possibility of collison between the two planets is, however, almost negligible, since Pluto's orbit is inclined by some 17° – very much more than that of Neptune, or indeed any other planet. Some astronomers believe that Pluto is a former satellite of Neptune.

Below: The orbit of a possible tenth planet, planet X, whose existence was predicted as a result of computer studies by American astronomer Joseph Brady in 1972. Brady maintains that a planet three times more massive than Saturn is causing the irregularities observed in the orbit of Halley's comet. It circles the Sun in a retrograde (clockwise) direction at a distance of some 10,000 million km (6200 million mi) and takes 464 years to complete one orbit. Its orbital plane is inclined 60° to that of the Earth.



'THE UNIVERSE' - SAMPSON LOW © 1975

OMNI – OCT. '78

STARS

By Patrick Moore, O.B.E.

Last night I went into my observatory, uncapped my telescope, and pointed it in the direction of the planet Pluto. There was the tiny, remote world—looking like a dim star, and yet so profoundly unstarlike. Generally it is regarded as the outermost planet—but this is not always true—and many astronomers feel that Pluto shouldn't be there at all!

Pluto was tracked down in 1930 as the result of calculations by the American astronomer Percival Lowell, best remembered today for his fascinating (and, alas, completely erroneous) ideas about the canals of Mars. Lowell based his calculations on the disturbing effects of a then-unknown source upon the giant worlds Neptune and Uranus, and had, so to speak, carried out a detective's investigation in reverse. He was right; Pluto proved to be just where he had plotted it.

Yet—something was wrong. Pluto was found to be very small, with a diameter less than that of the earth or even of Mars. How could such a midget planet possibly drag Uranus or Neptune out of position by any measurable amount? Yet it was by these very perturbations that Pluto had been discovered. It was all very odd; and to make matters worse, Pluto has an orbit that periodically brings it closer to the sun than Neptune (although there is no chance of collision). From January 1979 to the year 1999, Neptune, not Pluto, will be the outermost planet of our solar system!

What is the nature of the peculiar Pluto discovery? No one yet knows.

In the meantime there has been an exciting development with Pluto. Studies carried out at the Flagstaff, Arizona, station of the U.S. Naval Observatory and at Cerro Tololo Observatory in South America indicate that Pluto may have a satellite, or moon, with a diameter larger than half the diameter of Pluto itself! The moon seems to circle Pluto once each Plutonian day (about 6¼ earth days), and is about 20,000 kilometers away. It is still too early to be sure, but the satellite may well be there—in which case, it would make Pluto a double, or binary, planet.

Might there be another planet far beyond either Neptune or Pluto? If so, what are the chances of finding it? It must be cold, lonely, and remote beyond all understanding; from it, the sun would only be as brilliant as the full moon condensed to the size of a brilliant star. Tracking down such a world would be a Herculean task. But Planet Ten is a good possiblity, and its discovery might help explain the history of the outer reaches of the solar system.

• • •

Speaking of satellites, another recent report is of real interest, this time concerning the asteroids or minor planets—dwarf worlds orbiting the sun in the gap in the solar system between the orbits of Mars and Jupiter. One of them, a very faint body 240 kilometers across, is named Herculina. On June 7 Herculina passed in front of a somewhat brighter star and occulted (hid) it for a few seconds. Remarkably, that star winked not once but twice—from this startled observers in California inferred that the asteroid Herculina may not be a solitary wanderer. According to calculations by David W. Dunham of the International Occultations Timing Association, Herculina may have a satellite of its own, some 50 kilometers across and 1000 kilometers away.

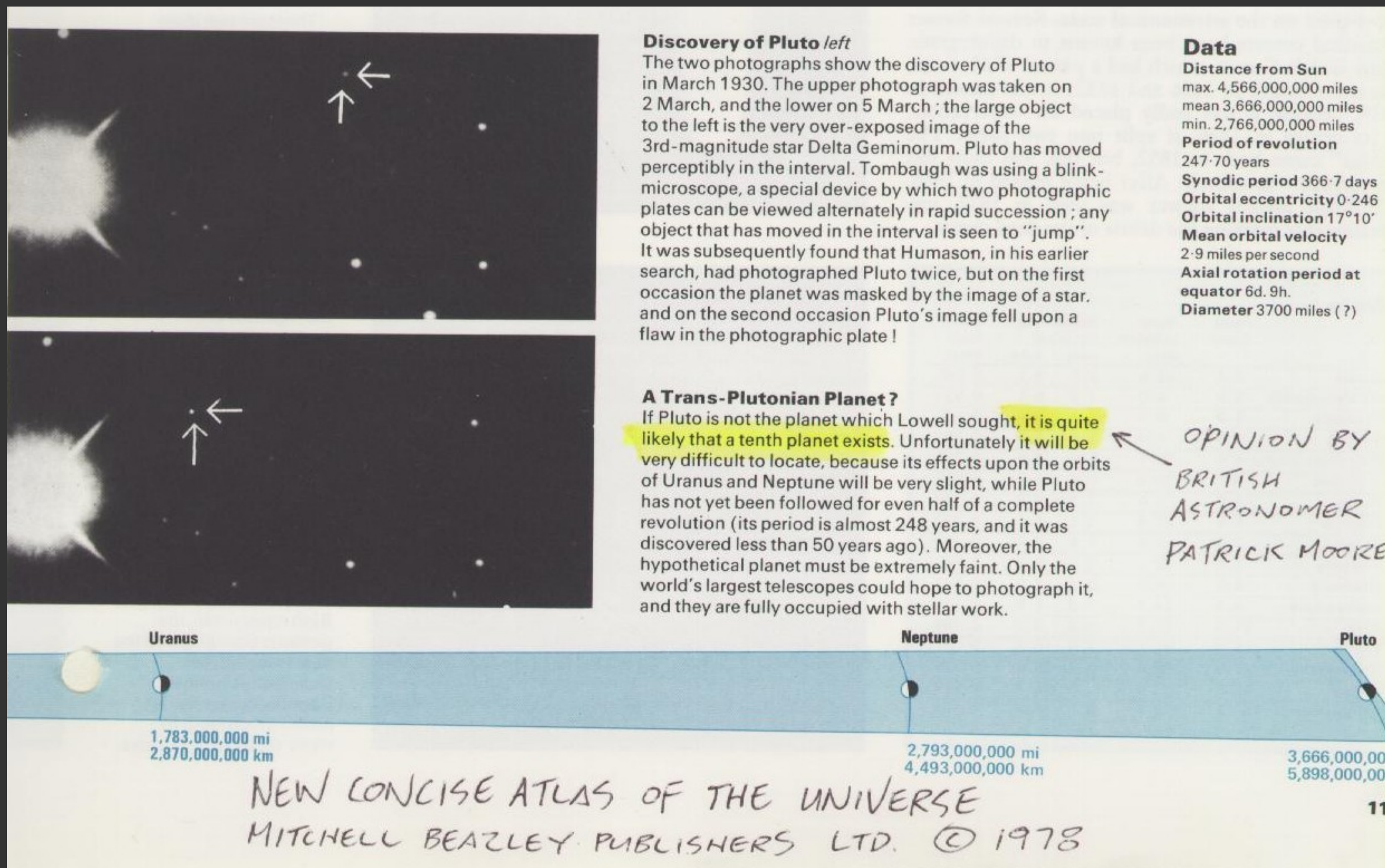
Herculina may not be the only asteroid so honored. The idea that minor planets could have satellites was first conjectured as long ago as 1901. Several astronomers in the 1920's and 1930's made observations that seemed to indicate that the large minor planets Eros and Pallas have companions. In recent years those reports have been confirmed by other observers watching those asteroids occult stars.

Asteroids could be troublesome little bodies. When the first two *Pioneer* spacecraft went out toward mighty Jupiter, they had to pass right through the asteroid belt, and there was serious fear that they might be destroyed colliding with a chunk of cosmic debris. Luckily that did not happen—there may be fewer very small asteroids than we once thought—but a hit from a sizable piece of rock would destroy any probe in a fraction of a second. We can only hope a means of protection more reliable than luck will be devised before human beings start to invade those perilous regions.

We will, of course, go there someday.

The Jenner Files:

Irrefutable Planet X Evidence



Discovery of Pluto *left*

The two photographs show the discovery of Pluto in March 1930. The upper photograph was taken on 2 March, and the lower on 5 March; the large object to the left is the very over-exposed image of the 3rd-magnitude star Delta Geminorum. Pluto has moved perceptibly in the interval. Tombaugh was using a blink-microscope, a special device by which two photographic plates can be viewed alternately in rapid succession; any object that has moved in the interval is seen to "jump". It was subsequently found that Humason, in his earlier search, had photographed Pluto twice, but on the first occasion the planet was masked by the image of a star, and on the second occasion Pluto's image fell upon a flaw in the photographic plate!

A Trans-Plutonian Planet?

If Pluto is not the planet which Lowell sought, it is quite likely that a tenth planet exists. Unfortunately it will be very difficult to locate, because its effects upon the orbits of Uranus and Neptune will be very slight, while Pluto has not yet been followed for even half of a complete revolution (its period is almost 248 years, and it was discovered less than 50 years ago). Moreover, the hypothetical planet must be extremely faint. Only the world's largest telescopes could hope to photograph it, and they are fully occupied with stellar work.

OPINION BY BRITISH ASTRONOMER PATRICK MOORE

Data

Distance from Sun
max. 4,566,000,000 miles
mean 3,666,000,000 miles
min. 2,766,000,000 miles
Period of revolution
247·70 years
Synodic period 366·7 days
Orbital eccentricity 0·246
Orbital inclination 17°10′
Mean orbital velocity
2·9 miles per second
Axial rotation period at equator 6d. 9h.
Diameter 3700 miles (?)

Uranus
1,783,000,000 mi
2,870,000,000 km

Neptune
2,793,000,000 mi
4,493,000,000 km

Pluto
3,666,000,000
5,898,000,000

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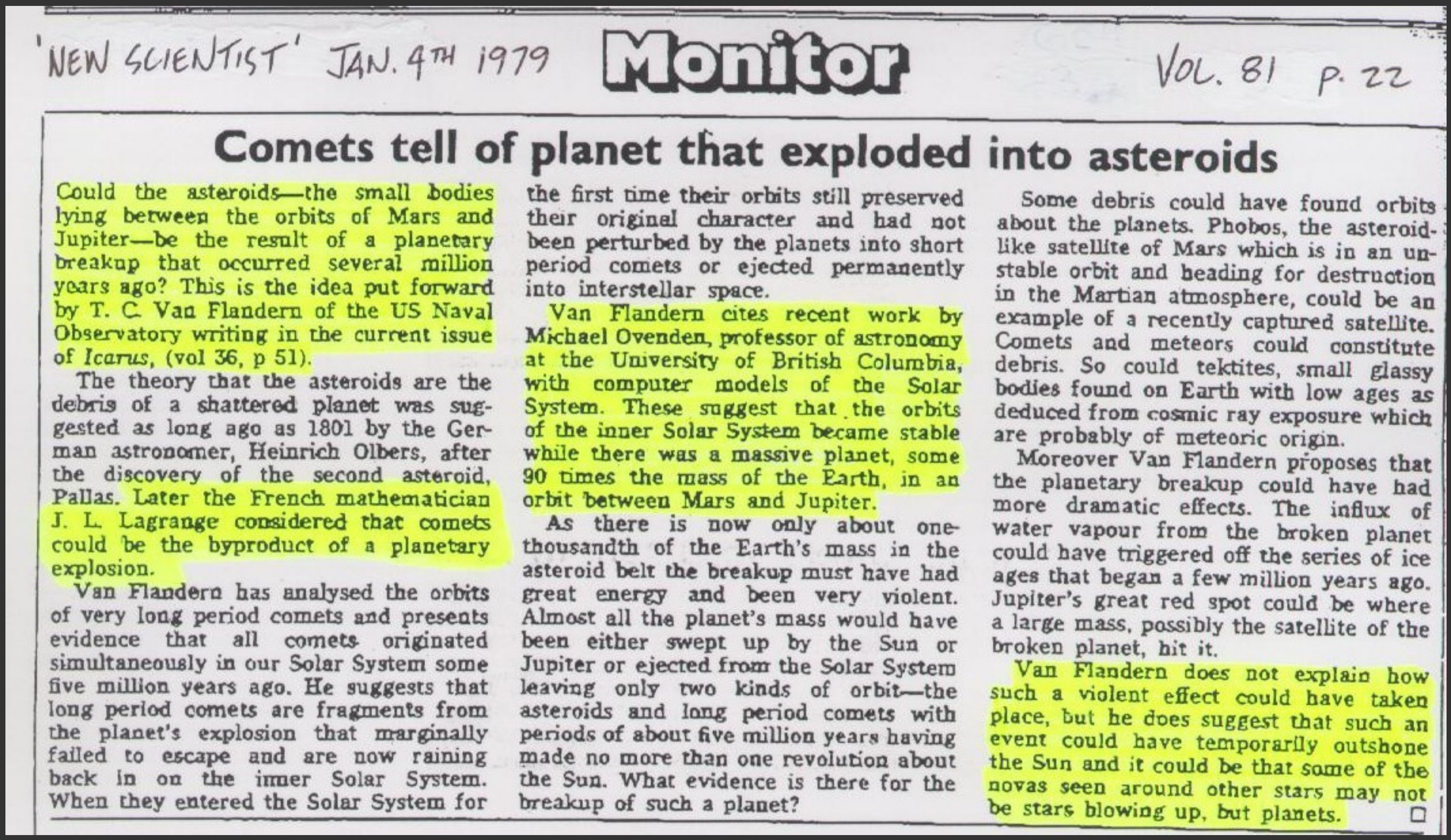
NEW CONCISE ATLAS OF THE UNIVERSE
MITCHELL BEAZLEY PUBLISHERS LTD. © 1978



'NEW SCIENTIST' JAN. 4TH 1979 **Monitor** VOL. 81 P. 22

Comets tell of planet that exploded into asteroids

Could the asteroids—the small bodies lying between the orbits of Mars and Jupiter—be the result of a planetary breakup that occurred several million years ago? This is the idea put forward by T. C. Van Flandern of the US Naval Observatory writing in the current issue of *Icarus*, (vol 36, p 51).

The theory that the asteroids are the debris of a shattered planet was suggested as long ago as 1801 by the German astronomer, Heinrich Olbers, after the discovery of the second asteroid, Pallas. Later the French mathematician J. L. Lagrange considered that comets could be the byproduct of a planetary explosion.

Van Flandern has analysed the orbits of very long period comets and presents evidence that all comets originated simultaneously in our Solar System some five million years ago. He suggests that long period comets are fragments from the planet's explosion that marginally failed to escape and are now raining back in on the inner Solar System. When they entered the Solar System for the first time their orbits still preserved their original character and had not been perturbed by the planets into short period comets or ejected permanently into interstellar space.

Van Flandern cites recent work by Michael Ovenden, professor of astronomy at the University of British Columbia, with computer models of the Solar System. These suggest that the orbits of the inner Solar System became stable while there was a massive planet, some 90 times the mass of the Earth, in an orbit between Mars and Jupiter.

As there is now only about one-thousandth of the Earth's mass in the asteroid belt the breakup must have had great energy and been very violent. Almost all the planet's mass would have been either swept up by the Sun or Jupiter or ejected from the Solar System leaving only two kinds of orbit—the asteroids and long period comets with periods of about five million years having made no more than one revolution about the Sun. What evidence is there for the breakup of such a planet?

Some debris could have found orbits about the planets. Phobos, the asteroid-like satellite of Mars which is in an unstable orbit and heading for destruction in the Martian atmosphere, could be an example of a recently captured satellite. Comets and meteors could constitute debris. So could tektites, small glassy bodies found on Earth with low ages as deduced from cosmic ray exposure which are probably of meteoric origin.

Moreover Van Flandern proposes that the planetary breakup could have had more dramatic effects. The influx of water vapour from the broken planet could have triggered off the series of ice ages that began a few million years ago. Jupiter's great red spot could be where a large mass, possibly the satellite of the broken planet, hit it.

Van Flandern does not explain how such a violent effect could have taken place, but he does suggest that such an event could have temporarily outshone the Sun and it could be that some of the novas seen around other stars may not be stars blowing up, but planets. □

OMNI FEB. '79

SHOALS OF SPACE

STARS

By Patrick Moore

I began a recent lecture by stating that for the benefit of absolute beginners I would spend a few moments going back to square one—anybody who knew the difference between an asteroid and an adenoid could take a quick nap. Many people in the audience had no idea what an asteroid was, but asteroids are important, if only because they have been regarded as real hazards to spacecraft traveling through the solar system.

At the moment we have had four vehicles (two *Pioneers* and two *Voyagers*) that have threaded their way through the danger zone without meeting disaster. This may indicate that there is less cause for concern than was supposed regarding the density of the asteroid belt. But it would be foolish to be overconfident, for one simply cannot maneuver a spaceship, manned or unmanned, to dodge an asteroid as it happens along.

Asteroids are dwarf planets. Most of them move around the sun between the orbital paths of Mars and Jupiter, thereby dividing the solar system neatly into two parts. Ceres, the largest asteroid, is no more than 1100 kilometers across, and there are many members of the swarm that are no more than a kilometer or two across. Only one, Vesta, is ever visible to the naked eye, and even Vesta appears only as a dim, starlike point.

Oddly enough, the asteroid belt—or, rather, a planet in the same region—was predicted, prior to the nineteenth century, long before it was actually found. Two German astronomers, Titius and Bode, calculated a mathematical relationship linking the distances of known planets from the sun. Their calculations indicated a gap in the solar system between the orbits of Mars and Jupiter.

Known as Bode's law, it was, in fact, first drawn up by Titius (science is not always logical). Frankly, I have a profound distrust of the law, and regard it as being in the category of those juvenile "take-away-the-number-you-first-thought-of" games. Yet when first proposed it was taken quite seriously.

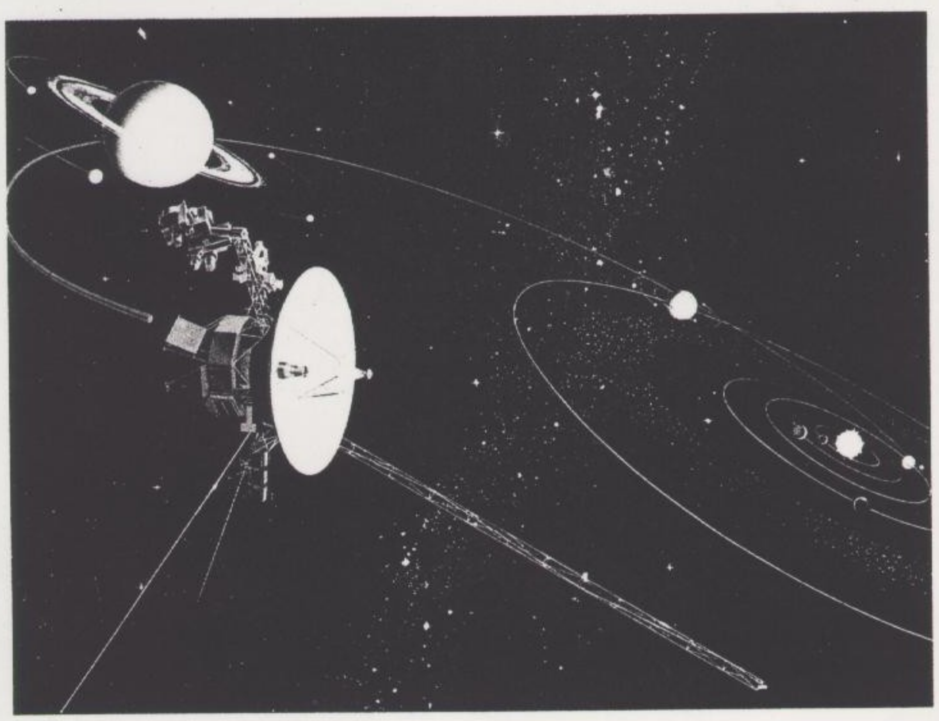
Some asteroids may wander away from their main orbital zone and approach the earth. In 1937 Hermes, a mere kilometer in diameter, brushed past us as close as 775,000 kilometers, less than twice the distance to the moon. One British newspaper printed the memorable headline "World Disaster Missed by Four Hours: Tiny Planet Whizzes Past." There is always a chance of a direct hit; and the damage, while it may not result in worldwide devastation, would be quite serious.

Other peculiar asteroids are known. One, Icarus, goes within 25 million kilometers of the sun, so that at times it must be red-hot. Another, Eros, is shaped like a cosmic sausage, 29 kilometers long and about 14 kilometers wide. We also have a true oddity, Chiron, which wanders around the solar system between the paths of Saturn and Uranus. Whether Chiron is a real asteroid we still don't know—it is approximately 640 kilometers across, which by asteroidal standards is large. What made the asteroid belt? One theory is that a planet in that part of the sun's family exploded for some unknown reason. It may be that there were two old planets that met head-on, with cataclysmic results. Or, more plausibly, the asteroids were produced from material that never formed into a larger body.

They must be barren worlds—bleak, airless, waterless, and lifeless. Go to one, and you will weigh little more than a postage stamp. You would be able to leap clear from a small asteroid by sheer muscle power, thereby becoming a tiny independent planet in your own right.

There have been suggestions of mining valuable minerals from asteroids (if such material exists). Perhaps their best use might be as unmanned observatories—particularly Icarus, from which the sun would be magnificent indeed. But well-placed probes *could* tell us the mineral value of asteroids.

There was a film in which the hero went up in a spaceship, equipped with a large net, and began asteroid fishing. Even though, so far as I know, he had little luck, these dwarf planets are full of interest. Surely we must hold them in less contempt now that we have successfully navigated these shoals in space. ∞



Two Pioneer unmanned vehicles have successfully passed through the asteroid belt.

The Jenner Files:

Irrefutable Planet X Evidence

'MYSTERIOUS UNIVERSE'
A HANDBOOK OF ASTRONOMICAL ANOMALIES
BY: WILLIAM R. CORLISS © 1979
THE SORCEBOOK PROJECT INC.

NEW PLANET MAY BE ADDED TO THE SUN'S FAMILY OF NINE

Anonymous; *Science Newsletter*, 41:361, 1942.

A new planet about the size of Pluto but a little less distant may be added to the sun's family, which already contains nine members.

No such tenth member has yet been found, but the attraction of such a body would account for the three days' delay in the return of Halley's comet in 1910, according to the calculations of Dr. R. S. Richardson of Mt. Wilson Observatory reported in the Publications of the Astronomical Society of the Pacific (February). And he has told astronomers just where to look for the new body. It should now be found, he says, at about right ascension 16 hours, declination minus 20 degrees. These figures enable astronomers to point their instruments directly at the suspected spot.

At first, Dr. Richardson thought Pluto might be the culprit that held back Halley's comet. But it turned out that Pluto was miles away at the time---in fact, more than three billion miles away. This was the very closest the planet ever got to the comet, and it happened in October, 1901. Also Pluto is so tiny, only about as big as the earth! Finally, Dr. Richardson's very careful calculations showed that if Pluto had any effect at all, it was in the wrong direction; it would have hastened rather than delayed the comet.

. . . .

What is needed to explain the comet's dilatory behavior, Dr. Richardson found, is a planet whose orbit just grazes the furthermost tip of Halley's orbit, grazes it by about 9,000,000 miles. The planet would be about the size of Pluto or the earth. A larger planet at a greater distance would also do the trick, but the planet must be small because otherwise it would have been discovered.

If this planet is found, it will be the third to have been predicted mathematically and afterwards discovered. The other two are Neptune, discovered in 1846 from the calculations of Leverrier and Adams, and Pluto, discovered in 1930 from the calculations of Lowell and Pickering.

A FORMER MAJOR PLANET OF THE SOLAR SYSTEM

Van Flandern, T. C.; *EOS*, 57:280, 1976.

Abstract. Recent dynamical calculations by M. W. Ovenden have demonstrated the former existence of a 90-Earth-mass planet in the asteroid belt until $16x10^6$ years ago. These calculations have now been strikingly confirmed by the discovery that very-long-period comets apparently originated in the explosion of such a planet at that epoch. The evidence from comets is present in the distributions of each orbital element; but the most compelling evidence comes from a backwards integration of 60 well-observed very-long-period comets to their previous perihelion passage, which shows that most of these intersect at

nearly the same point on the heliocentric celestial sphere. Taken in conjunction with the already existing evidence, these new results leave little room to doubt that a Saturn-sized planet did exist between Mars and Jupiter 16 million years ago, and then violently exploded.

COMETS AND CLIMATIC CHANGES

Anonymous; *Nature*, 176:1152-1153, 1955.

In a paper entitled "Evidences Cometaires des Variations des Climats" (Bull. Astro. Inst. Czechoslovakia, 6, No. 1; 1955), F. Link and Z. Linkova deal with statistical research relating to the discovery of comets, correlated with solar activity. They have found that the annual number of comets discovered varies in the course of the solar cycle of eleven years. This variation is inversely proportional to rainfall, with two maxima during the eleven years, according to Helman's investigations, and more recently it has been found that the number of comets discovered during a cycle is greater in the even than in the odd cycles. The numbers of comets discovered between 1755 and 1953 are arranged in cycles 1-18, and then the mean number of discoveries per year in the successive cycles is given separately for even and odd cycles. The influence of the meteorological conditions on the observations of comets is shown by means of a graph. Solar activity being greater during the odd cycles, the circulation in the terrestrial atmosphere is increased, and in consequence observations become more difficult; as a result of this, there is a decrease in the number of comets observed.

This close connexion between the number of comets discovered and the meteorological conditions (the latter depending on solar activity) led the authors to carry out investigations on climatic variations since 1611, and the principle underlying this research is based on the assumption that the number of comets discovered is a function of three factors: the cosmic factor, that is, the actual number of comets that approached the Earth; the climatic factor, or the atmospheric conditions in civilized countries, which only need be included, as observations of comets in uncivilized countries would be useless for statistical purposes; the social factor or human activity (in particular, astronomical activity) in civilized countries. While the first factor can be regarded as constant, the second would increase in a more-or-less continuous manner in time, and the third would be revealed in the slope of the curve $N = f(A)$, N being the number of comets discovered from zero year up to the year A. Both these quantities have been taken from a catalogue by Baldet ("Ann. Bur. Long", Supp. 1950), and a searching analysis of the results leads to certain conclusions on the meteorological conditions between the years 600 B.C.-A.D. 1740. A comparison is made between these and the data given by C. E. P. Brooks in "Climate through the Ages", covering about a thousand years up to comparatively recent times, and there is a close accordance between them. The Czechoslovak workers hope to carry out further investigations on the subject.

The most exciting possibility is that another undiscovered planet exists somewh[...] beyond the orbit of Pluto. Fantast[...]s the idea sounds it seems the best explanation of the discrepancies in the orbits of Uranus and Neptune. Some astronomers have even tried to work out the characteristics of the mysterious planet. Latest calculations show it could be orbiting on average over 5700 million miles from the Sun. At this distance it would need to have a diameter of about 10,000 miles and a mass six times as great as the Earth.

In July 1978 another remarkable discovery was made from an observatory near Lowell's home in Flagstaff. An American naval astronomer, James Christy, was trying to refine details of Pluto's orbit when he noticed an apparent elongation in the image of the planet on a photographic plate. Subsequent studies have tended to confirm Christy's conclusion that the elongation is due to the existence of a moon orbiting close to Pluto. Christy has called it Charon for the mythological boatman who ferried souls into the underworld.

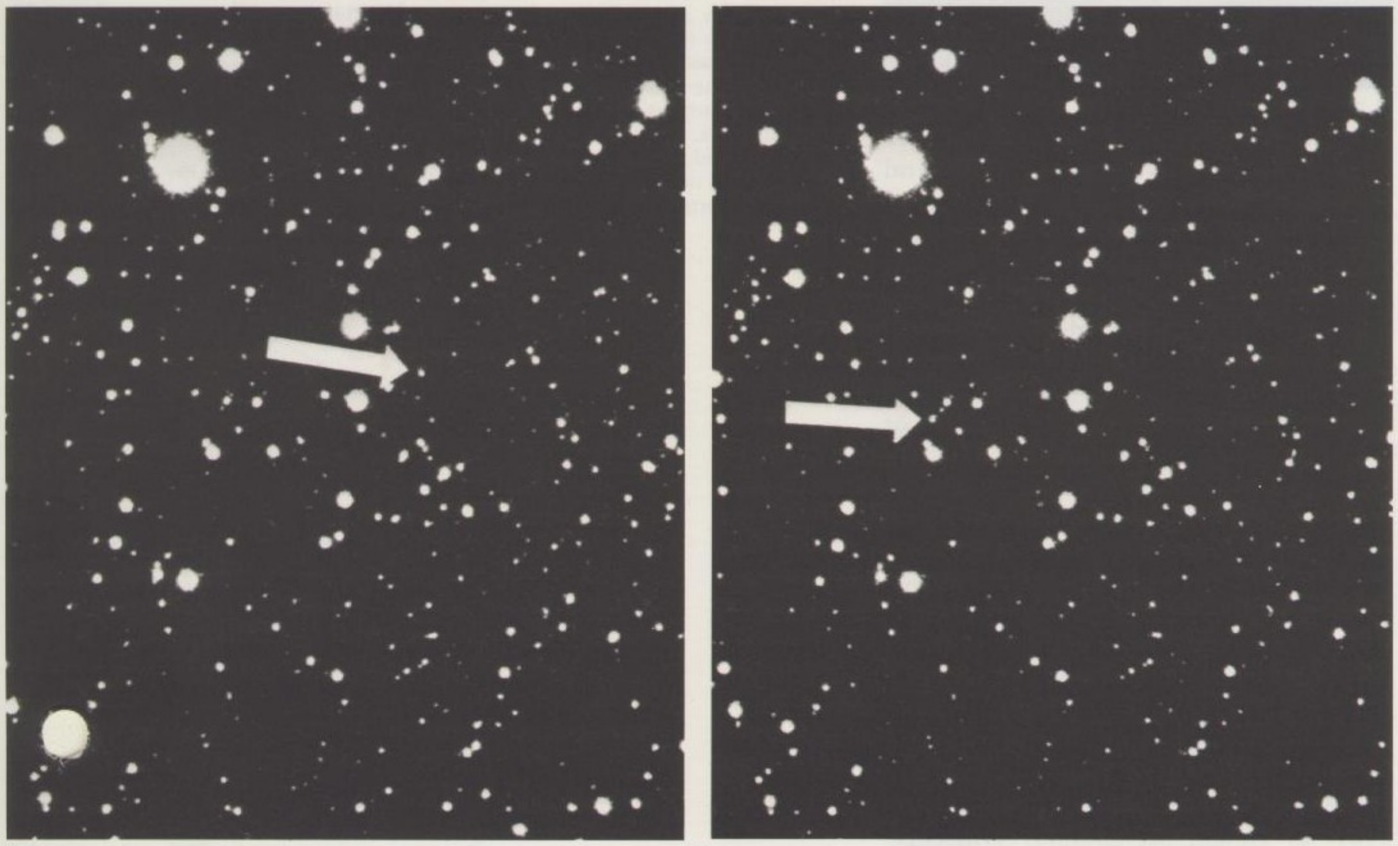
[...]ron is an extremely unusual satellite. [...]t appears to have a diameter about 40 percent that of Pluto, making it larger in proportion to its mother planet than any other satellite in the solar system. Even more remarkable is the fact that Charon orbits Pluto in 6.4 days, exactly the same time as it takes Pluto to complete a rotation on its axis. This means that Charon must hang stationary over one point on Pluto's surface, a phenomenon unique in the solar system.

Some astronomers even question whether Pluto is a true planet at all. Its similarity to some of the larger moons of the giant planets suggest it may actually have once been a moon of Neptune torn loose by some ancient cataclysm, perhaps even by the intrusion of the mysterious tenth planet.

At the moment scientists can only speculate about conditions on the surface of Pluto. Temperatures must be close to absolute zero and even if the planet had ever possessed an atmosphere, its gases would now lie frozen or liquefied on the surface. The Sun would appear as a bright star but its light would hardly be strong enough to illuminate Pluto's bleak landscape.

Pluto is a lonely outpost world. Beyond its remote orbit lies only the unresolved mystery of the tenth planet and then the vast gulf of interstellar space.

Below: two photographs taken by American astronomer Clyde Tombaugh at Lowell Observatory, Arizona, in 1930, show the planet Pluto (arrowed) for the first time. It had been predicted as early as 1905, when the American astronomer Percival Lowell showed that there had to be a ninth planet to account for small irregularities in the orbit of the recently discovered Neptune. Pluto had evaded earlier detection because it was unexpectedly faint. The planet remains largely a mystery. A moon was discovered around the remote planet in 1978, which led to a reassessment of its size – it is now thought to be both smaller and lighter than at first predicted.



'SPACE' – ALDUS BOOKS LIMITED LONDON © 1980

Lesson from history

10th planet? Pluto's orbit says 'yes'

By HUGH McCANN
News Staff Writer

If new evidence from the U.S. Naval Observatory of a 10th planet in the solar system is accurate, it could prove that the Sumerians, an ancient eastern Mediterranean civilization, were far ahead of modern man in astronomy.

Astronomer Thomas Van Flandern told a meeting of the American Astronomical Society in Albuquerque this week that irregularities in the orbit of Pluto, the farthest known planet from the sun, indicates that the solar system contains a 10th planet.

Pluto was the last planet discovered, in 1930. Since then, astronomers have been searching unsuccessfully for planets farther out. Indeed, Pluto had unknowingly been photographed but remained unrecognized for a long time because it was so difficult to see. Presumably, any other new planets would be easy to miss visually.

BUT THE heavenly body suspected by Van Flandern is making its presence felt in the same way that Pluto's presence was suggested — from the bulges that Pluto's gravitational field causes in the elliptical orbit of its closet neighbor, Neptune.

Now, says Van Flandern, subtle bulges detected in Pluto's orbit mean that there must be still another planet. He calculates that the unseen planet is four times the size of Pluto and 1.5 times its distance from the sun..

Van Flandern's announcement comes as no surprise to Zecharia Sitchin, whose book, *The 12th Planet*, came out three years ago.

SITCHIN, WHO describes himself as a Russian-born linguist and archeologist, says that the Sumerians, who date back 6,000 years, knew of a planet beyond Pluto. They counted it the 12th planet, he explains, because, in their system of reckoning, the sun and moon are also counted as planets. Its Sumerian name was Nibiru.

Continued on Page 12A

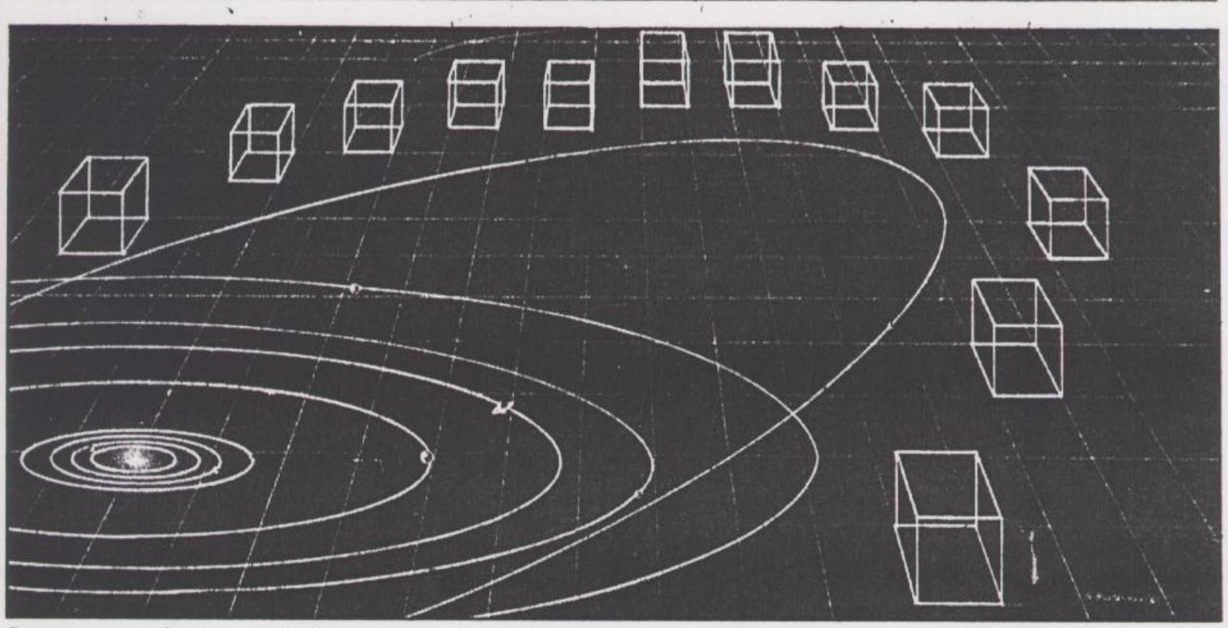
Sumerian tablet in East Berlin shows a solar system with sun, moon and 10 planets.

SCIENCE DIGEST: DEC. 1981

NEWSCIENCE

SEARCH FOR THE TENTH PLANET

Astronomers are readying telescopes to probe the outer reaches of our solar system for an elusive planet much larger than Earth. Its existence would explain a 160-year-old mystery.



Scientists are utilizing an IBM 4341 computer to combine educated guesswork with hard astronomical facts and come up with a list of likely regions past Pluto where a yet-undiscovered planet could be slowly circling the Sun. The pull exerted by its gravity would account for a wobble in Uranus' orbit that was first detected in 1821 by a French astronomer, Alexis Bouvard.

Beyond Pluto, in the cold, dark regions of space, may lie an undiscovered tenth planet two to five times the size of Earth. Astronomers at the U.S. Naval Observatory (USNO) are using a powerful computer to identify the best target zones, and a telescopic search will follow soon after.

Previous planetary observations show why astronomers believe a tenth planet may exist. In 1821, 40 years after the discovery of the seventh planet, Uranus, the French astronomer Alexis Bouvard noticed that its observed position did not agree with its calculated orbit. The planet was being perturbed, or pulled slightly off course, by the gravitational attraction of an outer planet. Working independently, an Englishman, John Couch Adams, and U.J.J. Leverrier of France used the discrepancy to calculate the theoretical position of an eighth planet, Neptune, which was finally spotted in 1846 by John Galle of the Berlin Observatory. But the mass of the new planet did not fully account for the distortion of Uranus' orbit, and so a search was begun for a ninth planet. Pluto was discovered by Clyde Tombaugh, working with photographic methods, on February 18, 1930.

However, tiny Pluto is 100 to 1,000 times too small to fully account for Uranus' wobble, according to Thomas Van Flandern of the USNO. A brief flurry of excitement followed Charles Kowal's 1977 discovery of the planetoid Chiron, orbiting between Saturn and Uranus, until it was determined that it was too minute to be planet 10. Van Flandern notes that the search for the planet "Vulcan," once proposed to account for Mercury's strange orbit, ended when Einsteinian physics revealed that the distortion of space caused by the Sun's huge mass created the irregularity. Another unexpected change in physical law is possible, he says, but "our best bet is for a tenth planet out there."

How to find it? First make some educated guesses about position and mass. Van Flandern thinks the tenth planet may have between two and five Earth masses and lie 50 to 100 astronomical units from the Sun. (An astronomical unit is the mean distance between Earth and the Sun.) His team also presumes that, like Pluto's, the plane of the undiscovered body's orbit is tilted with respect to that of most other planets, and that its path around the Sun is highly elliptical. By having an IBM 4341 computer match these assumptions against a huge quantity of astronomical data, the scientists obtained a list of places to start looking.

Although the computer has made their task a little easier, the astronomers don't count on finding a planet right away—the odds against it are literally astronomical. What will they call it if they do? Tradition says the name should come from Roman mythology, but as one researcher struggled over his calculations, he was heard to mutter something about "finding Humphrey." For the moment, the significance of this name remains as unclear as the location of the elusive planet. ■

Illustration by Robert Pasternak

The Jenner Files:

Irrefutable Planet X Evidence

Something lurking behind the planets

THE HUNT for a tenth planet is officially on, say American space scientists. A special conference held at NASA's Ames Research Center last week decided that the weight of evidence assembled at the US Naval Observatory, the Massachusetts Institute of Technology and the Jet Propulsion Laboratory in California is too strong to deny that something is lurking beyond the outer reaches of the known Solar System.

The research centres have pooled tens of thousands of observations of the giant, outer planets Uranus and Neptune. Anomalies in the planets' behaviour, say researchers, can be caused only by a large mass outside the orbit of Pluto. One of the earliest sources of this data is the work of Clyde Tombaugh, who discovered Pluto in 1930. Tombaugh attributed oddities in the orbit of Uranus to his new discovery. But the combined mass of Pluto and its satellite Charon is so small—only a fifth that of our own Moon—that this could not possibly be the explanation of the giant planet's strange behaviour.

The data presented at NASA's conference point to two explanations for the deep-space phenomenon. There may be a planet about the same size of Uranus some 5000 million miles beyond the orbit of Pluto. Or it could be something much bigger and further away. The problem for observers on Earth, says Archie Roy of Glasgow University, is that "The Sun could keep any number of planets out to a quarter of the distance to the nearest star, with no trouble."

NASA has its money on a more spectacular interpretation. According to John Anderson, the Jet Propulsion Laboratory's chief investigator, a dark star, companion to the Sun, might be the most likely explanation. The data suggest either a burnt-out white dwarf or a neutron star, perhaps 50 000 million miles from the Sun (12 times more distant than Pluto), or a black hole, 10 times the mass of the Sun at twice the distance. Support for these ideas is based on the Sun's lonely existence. Most stars are paired.

Observations on the Earth could confirm the presence of a tenth planet, or a second star, within a century. But NASA is looking for a quicker answer in the flights of Pioneer 10 and 11, the space probes now rapidly approaching the orbit of Pluto but travelling in opposite directions. NASA scientists can measure the speeds and positions of the craft so accurately that any unexpected variation in their paths would be an obvious sign of some huge, extra source of gravity. A dark star would affect the motion of both probes. If the extra member of the Solar System is somewhat smaller, its effects would register on only one.

Whatever the probes find, NASA is confident that there is something out there. If and when observers do find an extra planet, the benefits to the organisation will be in greater prestige—and perhaps more money—as much as in the romance of discovery. □

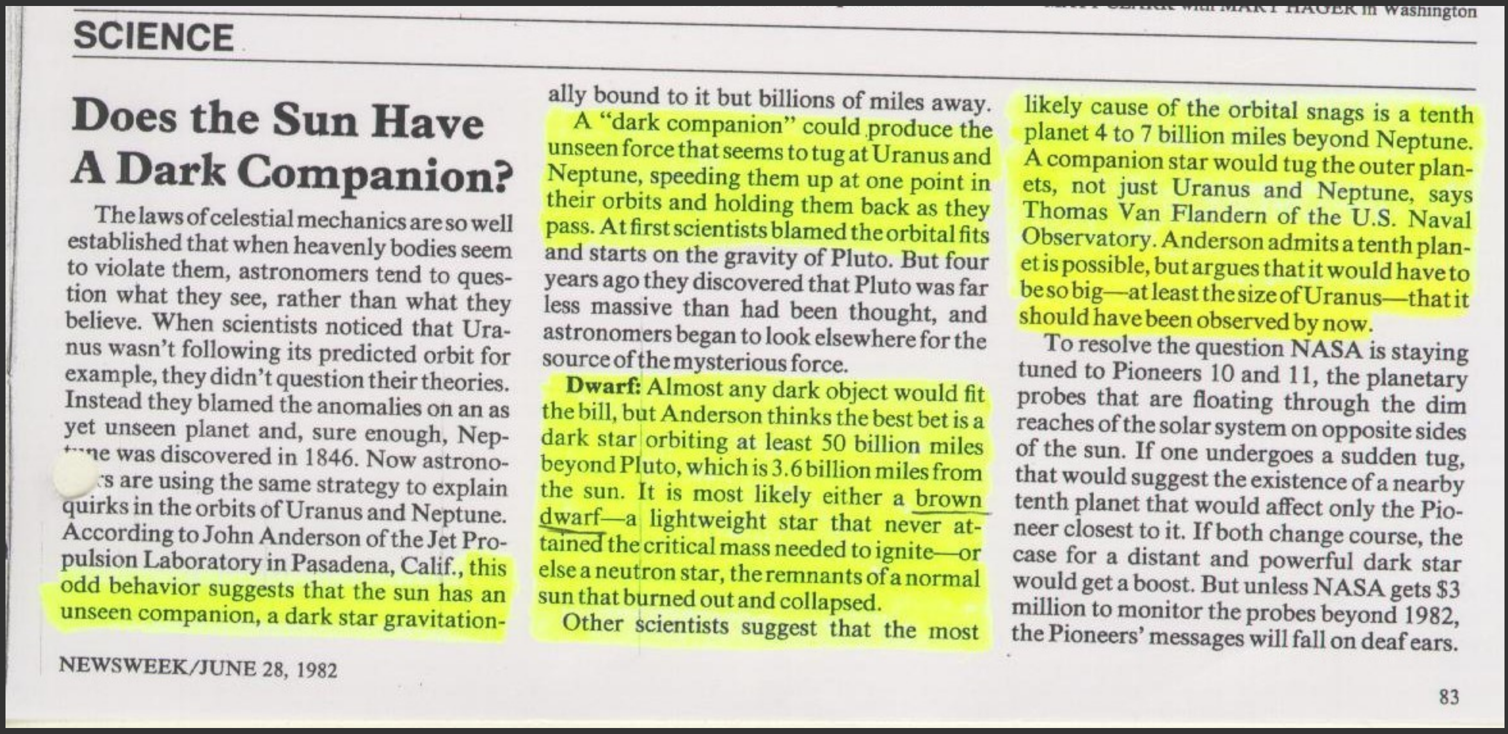

Derby Art Gallery

Looking for the tenth planet?

New Scientist 24 June 1982

The Jenner Files:

Irrefutable Planet X Evidence



MARY HAGER in Washington

SCIENCE

Does the Sun Have A Dark Companion?

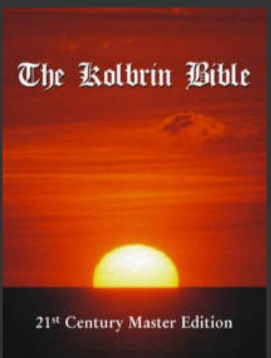
The laws of celestial mechanics are so well established that when heavenly bodies seem to violate them, astronomers tend to question what they see, rather than what they believe. When scientists noticed that Uranus wasn't following its predicted orbit for example, they didn't question their theories. Instead they blamed the anomalies on an as yet unseen planet and, sure enough, Neptune was discovered in 1846. Now astronomers are using the same strategy to explain quirks in the orbits of Uranus and Neptune. According to John Anderson of the Jet Propulsion Laboratory in Pasadena, Calif., this odd behavior suggests that the sun has an unseen companion, a dark star gravitationally bound to it but billions of miles away.

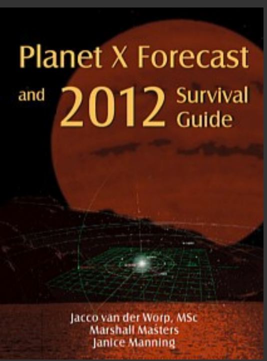
A "dark companion" could produce the unseen force that seems to tug at Uranus and Neptune, speeding them up at one point in their orbits and holding them back as they pass. At first scientists blamed the orbital fits and starts on the gravity of Pluto. But four years ago they discovered that Pluto was far less massive than had been thought, and astronomers began to look elsewhere for the source of the mysterious force.

Dwarf: Almost any dark object would fit the bill, but Anderson thinks the best bet is a dark star orbiting at least 50 billion miles beyond Pluto, which is 3.6 billion miles from the sun. It is most likely either a brown dwarf—a lightweight star that never attained the critical mass needed to ignite—or else a neutron star, the remnants of a normal sun that burned out and collapsed.

Other scientists suggest that the most likely cause of the orbital snags is a tenth planet 4 to 7 billion miles beyond Neptune. A companion star would tug the outer planets, not just Uranus and Neptune, says Thomas Van Flandern of the U.S. Naval Observatory. Anderson admits a tenth planet is possible, but argues that it would have to be so big—at least the size of Uranus—that it should have been observed by now.

To resolve the question NASA is staying tuned to Pioneers 10 and 11, the planetary probes that are floating through the dim reaches of the solar system on opposite sides of the sun. If one undergoes a sudden tug, that would suggest the existence of a nearby tenth planet that would affect only the Pioneer closest to it. If both change course, the case for a distant and powerful dark star would get a boost. But unless NASA gets $3 million to monitor the probes beyond 1982, the Pioneers' messages will fall on deaf ears.





World

VANCOUVER PROVINCE

Page A7
Friday
June 18, 1982

...es Russians at UN

But Soviet Ambassador Oleg Troyanovsky said: "I am not enthusiastic. This is definitely not a contribution to disarmament and peace."

Reagan portrayed the United States as the real champion of arms control and accused the Soviets of a "record of tyranny" that included violating existing arms control pacts and the 1925 Geneva protocol banning the use of chemical weapons.

Reagan assailed Moscow for stifling a budding peace movement at home, dominating Eastern Europe, building the Berlin Wall and supervising "the ruthless repression of the proud people of Poland."

"Soviet-sponsored guerrillas and terrorists are at work in Central and South America, in Africa, the Middle East, in the Caribbean and in Europe, violating human rights and unnerving the world with violence," Reagan said. "Communist atrocities in Southeast Asia, Afghanistan and elsewhere continue to shock the free world as refugees escape to tell of their horror."

"In Moscow (peace) banners are scuttled, buttons are snatched and demonstrators are arrested when even a few people dare to speak out about their fears."

Mystery of stars nearing solution

MOUNTAIN VIEW, Calif. (UPI) — A pair of American spacecraft may soon discover what mystery object — a tenth planet, a black hole or a visiting dark star — is throwing Uranus and Neptune (965 km) off course each year, NASA scientists said Thursday.

From data going back to Gallileo, Neptune and Uranus are known to be regularly pulled from their predicted orbits by gravitational force — but the cause of their deviation from their predicted orbits has never been determined.

A 1978 report by the U.S. Naval Observatory discarded a possible explanation, long favored, that the effect was produced by the planet Pluto. The theory was abandoned after the discovery of a satellite of Pluto, called Charon, leading to a recalculation of Pluto's mass.

Scientists found the Pluto-Charon mass was only about one-fifth the mass of the Earth's Moon, far too little to account for the tiny but regular shifts in the orbits of Neptune and Uranus.

They said a large, dark-star-type object perhaps as big as the Sun and perhaps 50 billion miles beyond the outermost planet could produce the orbital shifts in the two planets. A vastly larger black hole twice as far away is also consistent with the findings.

Or, according to the scientists, the pull of an undiscovered planet-sized object perhaps five billion miles beyond the Pluto-Neptune orbits would also explain the phenomenon.

The space agency said its scientists last summer began approaching the problem with data from Pioneer 10 and 11, the most distant man-made objects in the solar system. Data analysis will begin in October and an answer might come in three years.

ASTRONOMY BY J. ALLEN HYNEK

MYSTERIOUS PLANET X

I heard that a tenth planet or a star may exist in our outer solar system. Why do astronomers think this and how will they confirm it? *Jorge Esparza, Santa Ana, California*

Something must be out there, astronomers believe, because the orbits of Neptune and Uranus deviate slightly from what they should be, according to the laws of physics. A mysterious object—a planet or perhaps a "brown dwarf"—seems to be tugging them off course. Pioneers 10 and 11, American space probes headed beyond the planets, may serve as supersleuths that help identify and locate the source of these gravitational disturbances.

The deviation in the orbits of the two gaseous planets is tiny, only a matter of a few seconds of arc (one second of arc is the width of a penny as it would appear to the naked eye from 2.5 miles). But to astronomers this is a significant amount that needs to be explained. Neptune was discovered in 1846 because of its telltale gravitational pull on Uranus. Now, however, the unexplained deviations of Neptune and Uranus are much smaller than those that tipped off scientists more than a century ago. The new search hasn't been as easy.

For a while, Pluto was blamed for the effect. But with the 1978 discovery of the planet's small moon, Charon, Pluto's mass was found to be far too small for it to be the culprit. (Scientists have no direct way to figure out the mass of a planet that has no moon; the calculation is easy if a moon exists.) Pluto's mass is over 100 times less than was estimated; it's only 0.2 percent that of the Earth. Consequently, astronomers have cast their sights farther out.

Can the object be a planet? Or is it a brown dwarf—a star that didn't quite make it, a body not massive enough to produce the high internal temperatures necessary to ignite its nuclear furnace and thus shine like the sun? Or could it be a neutron star—a star that has gravitationally collapsed into a densely packed, dark remnant of its former luminous self?

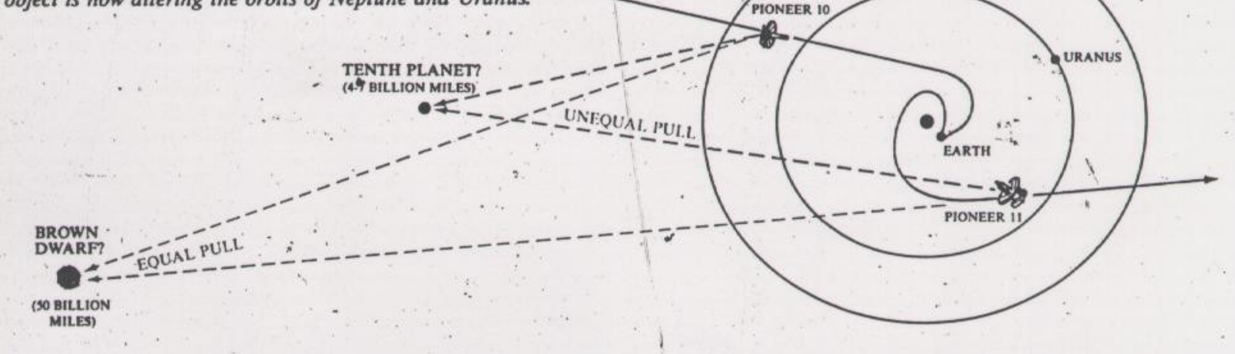
The two Pioneers, which are leaving the solar system in opposite directions, still transmit radio signals earthward. If they continue to do so for the next several years, astronomer John Anderson of the Jet Propulsion Laboratory will be able to calculate minute changes in their speeds, down to a fraction of an inch per second. Planet X, which would have to be relatively close by—between 4 and 7 billion miles away—to alter the orbits of Neptune and Uranus, would affect the closer spacecraft (Pioneer 10 in our diagram) but not the other. A brown dwarf or a neutron star—much more massive than a planet would be and located perhaps 50 billion miles away—would tug evenly on both Pioneers. If the results point to a brown dwarf, it will be the first of these theoretical objects to be identified.

A nearby brown dwarf may be located by another means. Although not hot enough to shine, such a dark star radiates in the infrared region of the electromagnetic spectrum. Planetary scientist Ray Reynolds and his colleagues at NASA Ames Research Center plan to use the Infrared Astronomy Satellite, scheduled for launch next month, to try to find a brown dwarf in our solar system or even farther out in space.

These theories have their critics. Planet X, skeptics say, would have to be as massive as Uranus to alter the paths of it and Neptune. Were that the case, it should long since have been discovered by conventional observations. As for its being a more distant, more massive body, Thomas Van Flandern of the U.S. Naval Observatory argues that the influence of such an object should have produced disturbances in the orbits of other planets—including the Earth.

(I'd like to thank Brenda Alexander of Kansas City, Missouri, and Steve MacDougall of Oakville, Ontario, for their questions on this same topic.)

As Pioneers 10 and 11 zip out of the solar system, tiny changes in their speeds may reveal just what type of object is now altering the orbits of Neptune and Uranus.



Is it possible to see stars during the day from the bottom of a deep well?

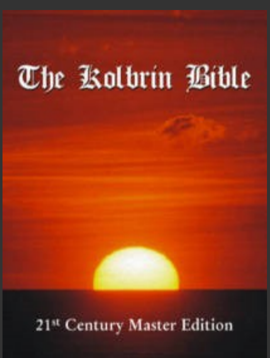
To test this bit of folk wisdom, I once tried it with a number of my students from Ohio State University, substituting a tall smokestack (an idle one!) for a deep well. Our cosmic target was the very bright star Vega in the constellation Lyra. This star passes directly overhead at the latitude of Columbus, Ohio, on autumn afternoons.

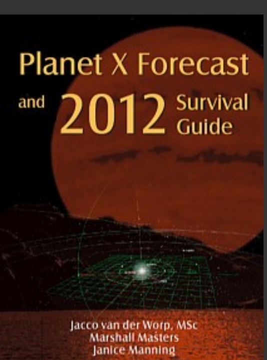
One clear day, we stationed ourselves at the bottom of the smokestack. The sky looked just as blue and bright from within our "well" as it had from the outside. At the precise moment Vega passed through our field of view, we saw nothing. Small binoculars didn't help; even blindfolding students beforehand to increase light sensitivity proved fruitless.

Perhaps the myth that stars can be seen from the bottom of wells, which has indeed appeared from time to time in literature, started with the Greek philosopher Thales (c. 636–c. 546 B.C.), who is said to have absentmindedly fallen into a deep well. He probably saw stars of a different order of magnitude.

J. Allen Hynek, Ph.D., professor emeritus of astronomy at Northwestern University, asks you to address your cosmic queries to the Astronomy Column, Science Digest, *888 Seventh Avenue, New York, New York 10106.*

Diagram by April Leigh Pahl, based on information in *Mercury News*, San Jose, CA





SPECULATIONS ON "PLANET X"
By Raymond C. Vaughan, Hamburg, New York
KRONOS Journal, Summer 1983, Volume VIII, Number 4

The idea that there is a tenth planet or other body beyond the orbit of Pluto is becoming popular among astronomers. At a conference held at NASA's Ames Research Center in June, 1982, a number of researchers discussed the growing evidence that something is out there: perhaps a planet, perhaps the remnant of a burned-out white dwarf or neutron star that was (is) a binary companion to the Sun, perhaps even a black hole.[1]

The evidence for such a body comes from the fact that the gravitational forces among the Sun and known planets cannot account fully for the observed orbital motions of the planets, particularly Uranus and Neptune, which show tiny unexplained deviations or perturbations from their predicted orbits. The same situation existed prior to the discovery of Pluto, and the belief that an unknown planet was causing the perturbations was in fact the motivation for the search that led to Pluto's discovery in 1930. Nowadays it is clear that Pluto was found for the wrong reasons; its mass is too low to produce the observed effects. Hence the new interest in finding a body out beyond Pluto.

SPECULATIONS ON "PLANET X"
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Continued...

Until more is known, it is easy to speculate about what could be out there. Astronomers at the NASA-Ames conference suggested a planet the size of Uranus at a distance of about 100 A.U. [1 A.U. = 93,000,000 miles, the distance from the Earth to the Sun] from the Sun, or a burned-out star at a distance of about 500 A.U., or a black hole (10 solar masses) at a distance of about 1000 A.U. Others have argued that the available evidence implies a body of 2 to 5 Earth masses, lying out of the plane of the ecliptic.[2]

From a Velikovskian perspective, there are also other possibilities. One is simply the idea that the perturbations could be minor effects of electrical or magnetic forces superimposed on the gravitational forces that are mainly responsible for the orbits. The source of such electrical or magnetic forces need not be a solid body but could be the sort of large-scale fields in space that Ralph Juergens envisioned.[3]

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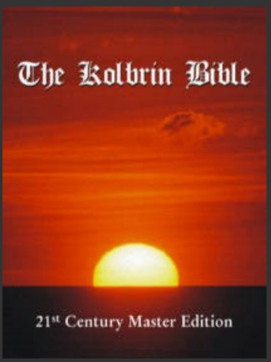
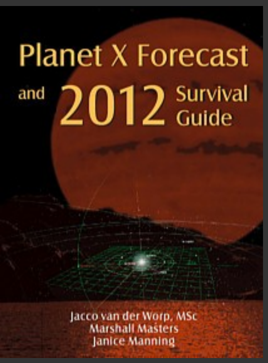
Another rather speculative possibility is that an unknown body does exist beyond the orbit of Pluto, that is it on a highly elliptical orbit with its perihelion well inside the orbit of Pluto, and that it participated in at least one of the planetary interactions described by Velikovsky.[4] For example, the unknown body could have passed near the orbits of Jupiter and Saturn several thousand years ago and could have participated in the birth of Venus. Or it could have passed through the inner solar system in the fifteenth century B.C. and have been the cause or catalyst of some of the Venus-Earth interactions.

To conjecture about the details of any such interactions seems fruitless without more information. However, there are some things that can be said about the range of possible orbits that would allow the unknown body to be: (1) close enough to engage the known planets in a Velikovskian interaction within the past several thousand years, (2) close enough to perturb the known planets at the present time, and (3) far enough away to remain unnoticed in the interim. Much depends on the mass of the unknown body but, since it left behind a reasonably intact planetary system, it must have been much smaller than the Sun.





SPECULATIONS ON "PLANET X"
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Continued...

Suppose we assume the unknown body to be no larger than Uranus and to be following an elliptical orbit that meets the above conditions. Its orbital period must be at least 3500 years, so its semimajor axis must be at least 230 A.U. If it is now close enough to perturb the outer planets, it cannot be more than about 100 A.U. from the Sun, which means that it cannot be moving away from the Sun. It must already have passed aphelion and be heading back toward the inner solar system. As can be seen from Table I [below], all of the applicable orbits have rather similar properties within 100 A.U. of the Sun, regardless of whether the orbital period is 3500 years or 14,000 years. If there is indeed an unknown body on such an orbit, it is heading toward the inner solar system at roughly 1 A.U./year and will reach perihelion in a century or less.

The idea that the body now perturbing the outer planets has a highly ellipitical orbit is of course pure speculation; it is generally consistent with but not necessarily a consequence of Velikovsky's theory. Within a few years, the nature of the unknown body may become much clearer;

SPECULATIONS ON "PLANET X"

By Raymond C. Vaughan, Hamburg, New York

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...astronomers are optimistic that its effect on the trajectories of Pioneer 10 and Pioneer 11 will be measurable as the two space probes move out past Pluto's orbit and will indicate the mass and location of the unknown body, even if it cannot be located visually. In the meantime, one can wonder whether the overall effect of a body returning to wreak interplanetary havoc in the solar system would be entirely bad. It could kill us all, though reports of previous encounters imply that some of us survived. Could it also make us realize the foolishness of our petty squabbles, over which we threaten to kill ourselves?

SPECULATIONS ON "PLANET X"
By Raymond C. Vaughan, Hamburg, New York
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Table I : Representative Elliptical Orbits

Perihelion (A.U.)	2	6	6	6
Orbital period (yr.)	2828	2828	8000	14697
Time (yr.) to reach perihelion from 100 A.U.	84	89	85	84
Radial velocity (A.U./yr.) at 100 A.U.	0.76	0.74	0.8	0.82
True anomaly* at 100 A.U.	165.9°	155.4°	153.4°	152.8°
Time (yr.) to reach perihelion from 40 A.U.	21	24	23	23
Radial velocity (A.U./yr.) at 40 A.U.	1.3	1.22	1.26	1.27
True anomaly* at 40 A.U.	155.4°	136.6°	135.5°	135.1°

* True anomaly is a planet's heliocentric longitude from perihelion. For a planet moving inward from aphelion to perihelion, both the true anomaly and the radial velocity would be negative.

SPECULATIONS ON "PLANET X"
By Raymond C. Vaughan, Hamburg, New York
KRONOS Journal, Summer 1983, Volume VIII, Number 4
Continued...

References

1. "Something lurking beyond the planets", New Scientist 94, 829 (24 June 1982). See also "Mysterious Planet X", Science Digest (Nov. 1982), p. 42.

2. "Search for the Tenth Planet", Science Digest (Dec. 1981), p. 17.

3. R.E. Juergens, "Electric Discharge as the Source of Solar Radiant Energy" (KRONOS VIII:1, pp. 3-14, and KRONOS VIII:2, pp. 47-62), and other pepers cited therein.

4. Cf. R.S. Harrington and T.C. Van Flandern, "The Satellites of Neptune and the Origin of Pluto", KRONOS V:2, pp. 48-56, for discussion of a non-Velikovskian orbital interaction involving the outer planets.

Your Own World USA

The Jenner Files:

Irrefutable Planet X Evidence

THIS WEEK

Has IRAS found a tenth planet?

Martin Redfern and Nigel Henbest

ASTRONOMERS are on tenterhooks this week. They are wondering what to make of reports that American analysis of data sent back by IRAS, the infrared telescope in space, has revealed a tenth planet beyond Pluto. Does the evidence stand up or, as some British astronomers were muttering early this week, is it all a bid to wring more money out of NASA for a new infrared space observatory.

IRAS has been a huge scientific success since its launch in January. But there has been growing tension between British and American astronomers over sharing out the spoils of the project, which is run jointly by the US, Britain and the Netherlands. The British say that the Americans keep breaking an agreement to make announcements of discoveries jointly.

The latest controversy surrounds an object discovered by IRAS in the constellation Sagittarius. The object's infrared emission shows that it has a temperature of around 230° K. This is too cool for a star yet to hot for a dust cloud. It could be a distant gaseous planet, several times heavier than Jupiter and giving off heat as its own gravity causes it to shrink in size. Whatever it is, say the British astronomers, the Americans have been keeping very quiet about it in recent weeks.

Meanwhile IRAS carries on watching. Hot on the heels of the Japanese discovery of a ring close to the Sun (last issue, p 340), comes the IRAS observation of what appears to be three more rings of dust circling the Solar System. Their temperature (around 150-200° K) suggests that they lie near the asteroid belt, between the orbits of Mars and Jupiter.

IRAS's project manager at Britain's Rutherford-Appleton Laboratory, Dr Eric Dunford, says that the rings are probably the results of asteroid collisions. The broad central band could have built up slowly during millions of years of the steady, microscopic chipping of boulders bumping around in space.


RAS

IRAS: surveying the Solar System

The other two bands may be the product of a single cataclysmic event, perhaps caused by a comet flying through the asteroids towards the Sun and demolishing an asteriod. Eventually, the dusty remains would have spread out to circle the Sun completely. The dust particles continue to orbit slightly irregularly, spending more time at the extremes of their wobble and thus appearing as two distinct bands.

IRAS is revealing that much of interstellar space is littered with whispy clouds of dust and gas, known as infrared cirrus. Their brightness around the infrared wavelength of 100 microns suggests that they are made up of graphite dust that has been ejected from stars as stellar wind and mixed up with ionised hydrogen gas.

Particularly striking are whisps of material that apparently come from the centre of the galaxy. Only in the infrared are these structures revealed with such clarity. The satellite has detected more than 200 000 infrared sources so far—100 times more than were previously known. Many do not fit into existing astronomical categories.

Some 130 cold, point-like sources have been selected for further investigation from an initial list of 8709 objects. Nine of these sources are completely new to science; it is not even known yet how far away they are. They could be just beyond the Solar System or, more likely, represent distant very young galaxies packed with hot, bright stars.

IRAS was launched on 25 January with an estimated 200-day life before its liquid helium refrigerant ran out and the telescope started to produce an infrared glow of its own. Now, hopes are revised, with the expiry date estimated at 7 January, 1984.

The wealth of data is proving a bit of an embarrassment to the three countries responsible. Budgets come to an end with preliminary analysis and the publication of a catalogue of infrared sources. But there is enough raw material for at least another three years' analysis. The British team is now pleading with the Science and Engineering Research Council for money to get the most out of the project, and to prepare the way for the European Infrared Space Observatory which will go into orbit at the end of the decade. □

● **New asteroid discovered, p 415**

OMNI - FEB. '83

PLANET 10

STARS

By Patrick Moore

One of the most fascinating questions in present-day astronomy is: Could there be a planet beyond Neptune? In other words, is there a tenth member of the solar system awaiting discovery?

I say beyond Neptune and not beyond Pluto, which is often considered the outermost, because Pluto is not a proper planet at all. Its diameter is a mere 1,440 miles, considerably less than that of the moon; even including its satellite, Charon, its mass is negligible by planetary standards; and what mass it has is mostly just ice. For these reasons, Neptune could more accurately be described as the outermost planet.

The saga of Planet 10 began around the turn of the century, when the American astronomer Percival Lowell began studying the motion of Uranus to see whether there were any perturbations in its orbit that might be caused by the gravitational influence of some unknown planet. Predicated on his studies of perturbations and his calculations, Lowell decided in 1905 that there was a ninth planet out there, and he went so far as to predict where it was located.

Pluto did show up not far from where Lowell had said it would be found, but in other respects it did not live up to his expectations. His work had suggested that Pluto would have a relatively large mass, similar to the earth's. When measured, however, Pluto was small. Almost entirely composed of ice, Pluto could not conceivably have caused these perturbations. This means that some celestial body other than Pluto was exerting this pull on the orbits of Uranus and Neptune. For these reasons astronomers believe either that Lowell's prediction of Pluto's location was a matter of sheer luck or that another planet, Planet 10, still awaits discovery.

I have never credited the idea that it was luck. It seems to be too much of a coincidence. And so in 1974 I made two suggestions how we should go about searching for the missing body. First, it is very likely that when Pluto was discovered, the unknown planet was right out there behind it. If this were true, we should be able to make a very rough and ready calculation of where it is now. Second, I suggested that man-made probes could provide us additional information for our search.

It was confirmed at a NASA conference in June 1981 that there were slight irregularities in the movements of both Uranus and Neptune that could have been caused by an unknown body. Also we already have two space probes tailor-made for investigating this further. They are *Pioneer 10* and *Pioneer 11*.

After bypassing Jupiter in December 1973, *Pioneer 10* began a never-ending journey away from the center of our solar system. Right now it is somewhere between the orbits of Uranus and Neptune. After its encounter with Saturn in 1979, *Pioneer 11* began its journey out of the solar system on a path diametrically opposite to the route taken by *Pioneer 10*. Its present position is somewhere between the orbits of Saturn and Uranus. With these two probes situated on either side of our solar system, we now have a real chance of locating another object, possibly a planet, beyond the orbit of Neptune.

Should that mysterious object be a planet, it would affect only one of the *Pioneer* craft, the one closer to it. If the perturbing body is something that is more massive—a dead star, for example—it would affect both spacecraft. Stars existing in pairs are common, and so it is entirely possible that the sun has a companion, a dying star of low luminosity, such as a black dwarf. OR BROWN

There is one more possibility: that the perturbing object is a black hole, from which nothing—not light, not matter—can escape. Its distance from Neptune's orbit would be on the order of 100 trillion miles, a distance that, by astronomical standards, is not all that far.

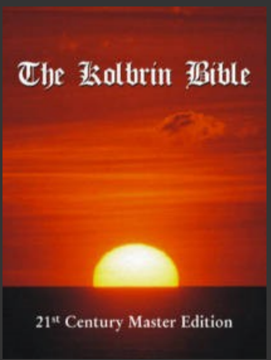
All this is highly speculative, but the evidence so far indicates that there is *something* out there at the edge of the solar system. Unknown planet? Dead star? Black hole? We cannot tell now, but if we can manage to stay in touch with the *Pioneers*, we may find out.

The planet Neptune: What is lurking out there beyond it—a black hole, a dead star, or Planet 10?

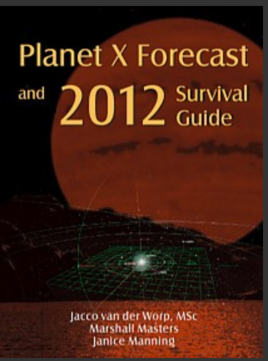
The Jenner Files:

Irrefutable Planet X Evidence

"Greg Jenner spent decades connecting the dots for this book. Now you can do the same, in a single evening!" *—Marshall Masters*



"The Kolbrin Bible is the Rosetta Stone of Planet X!"*—Greg Jenner*



"Required reading for those who get it and want to live through it."*—Echan Deravy, Solar Code*

JAN 30, 1983 PROVINCE

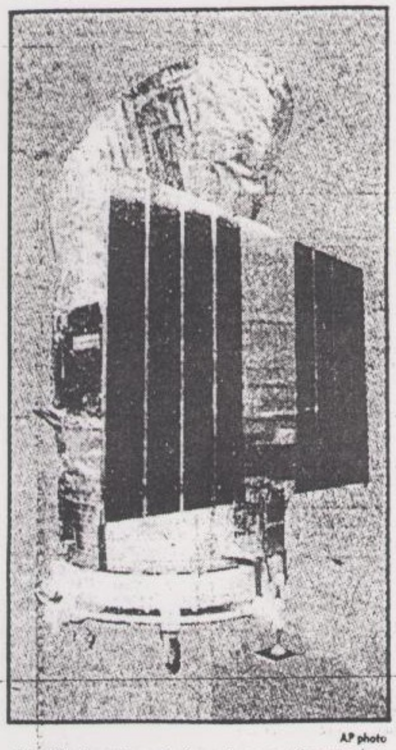
Space telescope poised to explore

Joint project plans survey of the galaxy

By JOHN NOBLE WILFORD
New York Times

NEW YORK — The first wide-ranging infra-red survey of the galaxy is set to begin soon with a recently launched telescope that should provide a new perspective on stars at the centre of the Milky Way and aid astronomers in their search for a 10th planet in the solar system.

Officials of the Jet Propulsion Laboratory in Pasadena, Calif., reported that the Infra-red Astronomical Satellite, launched last week, was operating smoothly in an orbit 900 kilometres above the Earth. Protective covers on the telescope are to be removed by radio command this weekend. After another week of engineering tests, the telescope is scheduled to begin searching for the "heat signatures" of stars and other objects that have previously gone undetected.



AP photo

Satellite housing an infra-red space telescope has its solar panels extended as it will look in space.

The 1,070-kilogram (2,360-pound) satellite was launched atop a Delta rocket from Vandenberg Air Force Base in California. The project is an $80-million venture involving the National Aeronautics and Space Administration, the Netherlands Aerospace Agency and the Science and Engineering Research Council of Britain.

Dr. Dale Compton, telescope manager at NASA's Ames Research Centre in Mountain View, Calif., estimates the instrument might produce at least a million previously unobserved sources of infra-red radiation in the sky. He said this would fill a significant gap in the electromagnetic spectrum between visible light and radio waves, about which "we have no or very little information."

Besides looking deep into the Milky Way and beyond, the 56-centimetre (22-inch) telescope should also find new objects in the solar system, including perhaps thousands of asteroids that have never been seen before. It should also provide astronomers with the first measurements of the size and reflectivity of the 3,000 asteroids already known.

In addition, the telescope will be used in the search for other planets of the Sun. Evidence from recent observations has led astronomers to renew the search for a long-suspected 10th planet, which is assumed to exist somewhere far beyond the orbits of Neptune and Pluto. Such a search, using ground-based optical telescopes in the early part of the century, led to the discovery of Pluto in 1930, the last known planet in the solar system.

Sir William Herschel, the English astronomer, discovered in 1800 the existence of an invisible form of radiation that he named infra-red. Many celestial phenomena invisible to the eye glow in infra-red. Astronomers for a long time were limited in their ability to detect sources of infrared radiation because water vapor and other gases in the atmosphere absorb it. The use of balloons, sounding rockets and high-altitude aircraft have since provided brief glimpses of infra-red-emitting objects.

With the new satellite telescope, however, astronomers expect to survey about 95 per cent of the sky over the next six months and produce the first comprehensive catalogue of infra-red objects.

To be able to sense a faint pinpoint of infrared heat in the sky, the telescope was designed to operate at a temperature of minus 270 C, just two degrees above absolute zero. The instrument is enclosed in a vessel filled with super-cold liquid helium. The length of the mission, about six months, is dictated by the time it will take the helium to boil off into space.

The satellite's orbit was chosen to reduce the chances of the telescope picking up confusing, perhaps blinding infrared signals from the sun, the moon or from other artificial satellites.

According to project astronomers, the telescope should pick up many cool, dark stars as well as brighter stars now hidden by clouds of dust that make them invisible from Earth. In particular, astronomers expect the telescope to penetrate some of the mysteries at the centre of our own galaxy.

The centre contains only one-millionth of the galaxy's volume, but it radiates one-tenth of the energy from the entire galaxy. Astronomers do not know why, because the region the energy comes from is largely hidden by interstellar dust.

THE VANCOUVER SUN

The Sun FRI., DECEMBER 30, 1983 ★★★ A 13

Orbiting eye reveals mystery space monster

By THOMAS O'TOOLE

WASHINGTON (TPS) — A heavenly body possibly as large as the giant planet Jupiter and possibly so close to earth that it would be part of this solar system has been found in the direction of the constellation Orion by an orbiting telescope called the Infrared Astronomical Observatory.

So mysterious is the object that astronomers do not know if it is a planet, a giant comet, a nearby "protostar" that never got hot enough to become a star, a distant galaxy so young that it is still in the process of forming its first stars or a galaxy so shrouded in dust that none of the light cast by its stars ever gets through.

"All I can tell you is that we don't know what it is," Dr. Gerry Neugebauer, IRAS chief scientist for California's Jet Propulsion Laboratory and director of the Palomar Observatory for the California Institute of Technology, said in an interview.

The most fascinating explanation of this mystery body, which is so cold it casts no light and has never been seen by optical telescopes on earth or in space, is that it is a giant gaseous planet as large as Jupiter and as close to earth as 80 trillion kilometres. While that may seem like a great distance in earthbound terms, it is a stone's throw in cosmological terms, so close in fact that it would be the nearest heavenly body to earth beyond the outermost planet Pluto.

"If it is really that close, it would be a part of our solar system," said Dr. James Houck of Cornell University's Centre for Radio Physics and Space Research and a member of the IRAS science team. "If it is that close, I don't know how the world's planetary scientists would even begin to classify it."

The mystery body was seen twice by the IRAS satellite as it scanned the northern sky from last January to November, when the satellite ran out of the supercold helium that allowed its telescope to see the coldest bodies in the heavens. The second observation took place six months after the first and suggested the mystery body had not moved from its spot in the sky near the western edge of the constellation Orion in that time.

"This suggests it's not a comet because a comet would not be as large as the one we've observed and a comet would probably have moved," Houck said. "A planet may have moved if it were as close as 80 trillion kilometres, but it could still be a more distant planet and not have moved in six months time."

Whatever it is, Houck said, the mystery body is so cold its temperature is no more than 20 degrees above "absolute" zero, which is 273 degrees celsius below zero. The telescope aboard IRAS is cooled so low and is so sensitive it can "see" objects in the heavens that are only 10 degrees above absolute zero.

When IRAS scientists first saw the mystery body and calculated that it could be as close as 80 trillion kilometres, there was some speculation that it might be moving toward earth.

"It's not incoming mail," Neugebauer said. "I want to douse that idea with as much cold water as I can."

Then, what is it? What if it is as large as Jupiter and so close to the sun it would be part of the solar system? Conceivably, it could be the 10th planet astronomers have searched for in vain. Is it a Jupiter-like star that started out to become a star eons ago but never got hot enough to become a star?

While they cannot disprove that notion, Neugebauer and Houck are so bedeviled by it that they do not want to accept it. Neugebauer and Houck "hope" the mystery body is a distant galaxy either so young that its stars have not begun to shine or so surrounded by dust that its starlight cannot penetrate the shroud.

"I believe it's one of these dark, young galaxies that we have never been able to observe before," Neugebauer said. "If it is, then it is a major step forward in our understanding of the size of the universe, how the universe formed and how it continues to form as time goes on."

The Jenner Files:

Irrefutable Planet X Evidence

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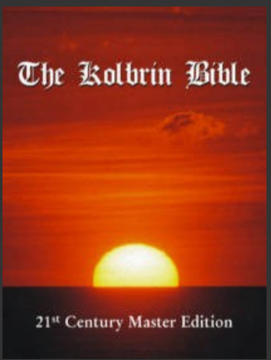

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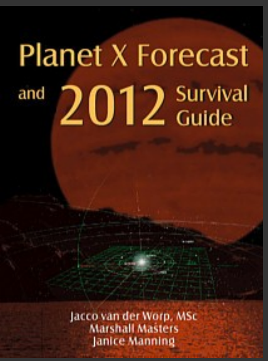

"Required reading for those who get it and want to live through it."—*Echan Deravy, Solar Code*

THE FRIGID WORLD OF IRAS — II

A Telescope in a Bottle

IRAS has given astronomers their first detailed survey of the far-infrared sky — in a sense, affording them the opportunity to view the universe anew. What made IRAS' mission particularly challenging, and even more gratifying, was its technological complexity. NASA had never before launched a cryogenically cooled telescope, despite decades of experience with spaceborne observatories.

To keep the project within reason, both technically and financially, responsibility was shared by three nations. The United States designed and built the telescope, provided the Delta launch vehicle, and is processing the data to its final form at the Jet Propulsion Laboratory. The Netherlands Agency for Aerospace Programs (NIVR) provided the rest of the 1,020-kg satellite and one of the experiments, then installed the completed telescope prior to launch. At Chilton, England, the U. K. Science and Engineering Research Council (SERC) built the single ground station that controlled the spacecraft and collected its data. These agencies shared IRAS' cost as well, about $119 million for NASA, $45 million for NIVR, and $25 million for SERC.

Crucial to IRAS' success was a blanket of superfluid helium that maintained the telescope at 2.4° Kelvin (−455° Fahrenheit) throughout the mission. A temperature this near absolute zero kept the spacecraft's thermal "noise" from blinding the detectors. IRAS' cryogenic Dewar, or vacuum-insulated enclosure, contained 72.3 kg of helium just before the satellite's launch on January 25, 1983 — an amount calculated to chill the telescope for a full seven months.

Once in orbit, however, the spacecraft consumed its helium much more slowly than expected. There was even hope (and a few bets) that the telescope would operate for a full year. But when the last bit of helium evaporated on November 21st the detectors quickly warmed and became useless, ending the mission. Still, the scientific team was elated with IRAS' 10-month performance. "No one thought the Dewar supply would last so long, or that the detectors would be so sensitive," notes Nancy Boggess, the project scientist at NASA.

The telescope itself was an f/9.6 Ritchey-Chrétien design with a 57-cm (22½-inch) primary mirror. At the focal plane, 17 rows of infrared detectors and eight star sensors were crowded into half of the 1°.1 field of view. A table on page 4 last month describes all the detectors except the Dutch experiment (a photometer and a low-resolution spectrometer operating from 7 to 24 microns).

Building the IRAS telescope proved a difficult technical challenge that had its rough moments. E. Kane Casani, who oversaw the fabrication at JPL, says the major problems were related to the supercold helium. One, of course, was welding the Dewar and its connections together so they didn't leak. Another involved designing a porous, yet leakproof, stainless-steel plug that would dissipate the helium's accumulated heat by allowing the fluid to evaporate slowly.

Some problems were unexpected. The telescope's beryllium optics, made by the Perkin-Elmer Corp. in Danbury, Connecticut, became noticeably pitted during polishing. The mirrors' metallic surfaces may have reacted with the polishing compound, but no one is certain about the cause. Particularly troublesome was achieving an optical figure that would remain accurate near absolute zero. Back at JPL, electronics failed and lenses cracked at the frigid operating temperatures. When the assembled telescope was filled with helium 11 months before launch, the entire 25-micron detector set would not work — one bad detector had shorted out all the rest.

With numerous technical problems awaiting solutions and costs mounting, the project found itself in serious difficulty. IRAS scientist Charles Beichman was worried, as were many others. "Someone should have taken a picture of what the telescope was like eight months before launch," he said after a NASA press conference on November 9th. "When we turned this thing on, I wouldn't have given you a plugged nickel for its chances. It looked as if we were going to have to tear it apart and have a year's delay. That didn't come across at today's happy, success-oriented meeting."

The fact is that IRAS was *very* successful. By the time its helium supply ran out, the telescope had scanned 95 percent of the entire sky twice and was three-quarters of the way through a third sweep (which would have been completed with two weeks' more helium). Along the way the spacecraft took time to "stare" at many objects or scan them repeatedly, yielding better sensitivity and spatial resolution than the normal survey scans provided.

By the end of this coming summer, the trinational IRAS team will publish a catalogue of the estimated 200,000-250,000 infrared point sources identified by the satellite. When the mission abruptly ended in November, about five percent of the sky had been seen only once or not at all; since a source must appear on two passes to be considered real, these areas will be excluded from the catalogue.

J. KELLY BEATTY

The first report of such observations involved three radio-loud and two radio-quiet quasars. The former all fall into the generic group known as "blazars" — compact radio sources that exhibit large optical or radio variations over short periods of time. IRAS observations of the blazars' far-infrared emission strengthens the current belief that these objects are powered largely by the synchrotron process.

The radio-quiet examples, on the other hand, seem to have excess emission at 100 microns, which may be coming from the underlying galaxies, presumably spirals, in which the quasars are embedded. This conjecture is supported by evidence, from ground-based studies, that the quasar-galaxy pair also has excess emission at shorter infrared wavelengths. Unfortunately, even though the IRAS data suggest the presence of the quasars' host galaxies, they do not tell us anything new about how the bright infrared glow arises.

Perhaps the most intriguing and fascinating of the IRAS findings are the unidentified point sources. Out of 8,709 sources found in the minisurvey, at least four have no known counterpart — no stars, nebulae, or galaxies. At a November 9, 1983, press conference J. Houck reported that these objects did not change their apparent positions over a period of many hours, so each must lie more than 30 a.u. away. However, there is no reason at present to assume that they lie outside our galaxy, or even outside our solar system. They could, in fact, be distant planets.

Specifically, the observations would fit a Jupiter-size object at a distance of some 570 a.u.; that far from the Sun, its temperature would be only 40° K. Such an object would have an apparent visual magnitude of about 18.3 and would likely have escaped discovery at visible wavelengths. If these IRAS sources are closer, say 30 a.u., they must also be very much smaller. On the other hand, if they do not show a measurable annual parallax during the course of the mission (after analysis), they must be at least 5,000 a.u. away.

But these and other "blank-field" sources could also be fainter or more distant examples of the very infrared-luminous galaxies found in the minisurvey, or perhaps highly evolved stars enshrouded in dense dust shells. The obscuration would have to be thick enough to hide the stars themselves at visible wavelengths, yet far enough away to maintain the observed low temperatures. At least some of the sources are probably either stars in the early stages of formation or very heavily obscured young stars.

Finally, of course, there is the possibility that IRAS has discovered an entirely new type of celestial object. That's what happened, for example, when the radio, X-ray, and gamma-ray regions of the spectrum were opened, and it might just happen again.

RONALD A. SCHORN

'ASTRONOMY' – APR. '84 (3)

they are very similar objects.

But RG 0050-2722's brief reign as the faintest known star ended last year when Ronald Probst and James Liebert found that the star LHS 2924 had a peculiar energy distribution and a very low temperature. On this basis they identified it as a black dwarf. It so happened that LHS 2924 was already on a parallax program being conducted by David Monet and Conard Dahn. They reported a preliminary distance for the star of 28 light-years, giving it an absolute magnitude of +20.0. For now, LHS 2924 is the intrinsically faintest star known.

Two other promising systems are Ross 614 and Wolf 424. Both are red dwarf binaries, and both exhibit motions that place them among the young disk population of stars. Ross 614 B has an absolute magnitude of only +16.5. In 1977 Ronald Probst claimed its mass to be $0.07 \pm 0.02\ M_\odot$ — probably below the critical mass. Wolf 424's two components are intrinsically brighter, at absolute magnitudes +15.0 and +15.2. A 1972 study estimated the masses of Wolf 424 A and Wolf 424 B to be $0.067 \pm 0.015\ M_\odot$ and $0.064 \pm 0.015\ M_\odot$, respectively.

When Is a Star Not a Star?

Not very long ago, the difference between a star and a planet was simple — stars twinkle, planets don't. But while this criterion may distinguish Mars from Antares, it is far too simplistic to deal with objects like black dwarfs.

Some astronomers reserve the term "star" for any object fueled by thermonuclear hydrogen fusion — one necessarily above the critical mass of $0.085\ M_\odot$. It seems unfair, however, to deny starhood to an object that can shine for hundreds of millions of years, even if its source of light is simple gravitational contraction. Although the time during which a subcritical mass object shines is brief compared to the Sun's age, it far exceeds the total lifetime of such stars as Rigel or Betelgeuse.

Banishing subcritical objects from the ranks of stardom creates two other problems. First, it means that if a star like VB 10 is one day found to be subcritical, it has been misclassified a star up to then and should no longer even appear in star catalogs. Second, it also means that in principle you cannot automatically call a shining object beyond the solar system and within the Galaxy a star. Instead, you must first verify that the source of its energy is nuclear fusion — a difficult and daunting task.

Therefore it seems much more reasonable to define a star as an object capable of forming independently of any other star. The smallest star that can form in a nebula is determined by the nebula's density and temperature. The greater the nebula's density and the lower its temperature, the smaller the star that can form. Although the minimum stellar mass is unknown, various astronomers suggest it is roughly $0.01\ M_\odot$. By our definition of a star, then, an object of Jupiter's mass — $0.001\ M_\odot$ — could never be a star, since it could not have formed in the absence of the Sun.

Well, then, how large can a planet be? Is there any definite demarcation in mass between stars and planets? Astronomer David Hughes has pointed out that the maximum planetary mass depends not on conditions in the stellar nursery, but on those in the protoplanetary disk surrounding a newborn star. Jupiter's mass of $0.001\ M_\odot$ may be about tops for a planet, and Hughes argues that objects with masses between the masses of stars and those of planets do not exist.

The ranks of such suspects may soon swell due to two space telescopes: IRAS and the Space Telescope. Launched last year, IRAS surveyed the sky at infrared wavelengths where these cool objects radiate predominantly (see "IRAS and the Infrared Universe," ASTRONOMY, March 1984). Scheduled for launch in about two years and concentrating on visible wavelengths, the Space Telescope will penetrate to apparent visual magnitudes of about +26. Based on these instruments' then-projected capabilities, astronomers R. Staller and T. de Jong predicted in 1981 that IRAS would probably fail to find any subcritical mass stars, although the Space Telescope should fare much better — they claimed it should discover an average of 90 per square degree, or almost 4 million over the entire sky.

In order to make such predictions, though, they assumed a total number of very-low-mass stars — and that question is controversial. Because of their intrinsic faintness, very-low-mass stars could abound throughout the Galaxy without being detected. Furthermore, since these stars remain visible for less than a billion years, many have vanished from view by now. If very-low-mass stars have formed at the same rate since the birth of the Milky Way, then every such star we find implies the existence of 10 to 20 others that have already cooled to invisibility. The abundance of suspect stars — VB 10, Ross 614 B, Wolf 424 A and B — within just 20 light-years of the Sun suggests that these stars are numerous.

On the other hand, they could also be quite rare. In 1982 Ronald Probst and Robert O'Connell published results of a search for very-low-mass stars in orbit about nearby white dwarfs. They chose white dwarfs because they're faint to begin with and are especially faint in the red and infrared, where very-low-mass stars shine most. (This helped lower the "noise" in detecting them.) Out of 107 white dwarfs, 15 proved double. Of these 15, only seven had red dwarf secondaries — and none of these red dwarfs had absolute magnitudes fainter than +15, despite the fact the survey would have found any as faint as absolute magnitude +20.7. The negative evidence is not conclusive, however. Perhaps something in the formation of a white dwarf disrupts a small orbiting star, or perhaps these white dwarfs are so old that any subcritical star in orbit about them has cooled too much and faded from view.

Astronomer Shiv Kumar has argued that many of the dark companions detected around nearby stars by Peter van de Kamp and others may be black dwarfs rather than planets, because many of the calculated masses lie above $0.01\ M_\odot$. (Jupiter's mass, $0.001\ M_\odot$, is probably close to the upper limit for a planet.) But van de Kamp's results have been seriously questioned by other astronomers (see "The Search for Extrasolar Planets," ASTRONOMY, December 1981) and are no longer thought to be reliable. If dark objects are ever found around other stars, orbital eccentricity may provide another method besides mass for distinguishing between black dwarfs and planets. Judging by our solar system, planets tend to have generally circular orbits. Stars in multiple systems, however, often have highly elliptical orbits. So a big

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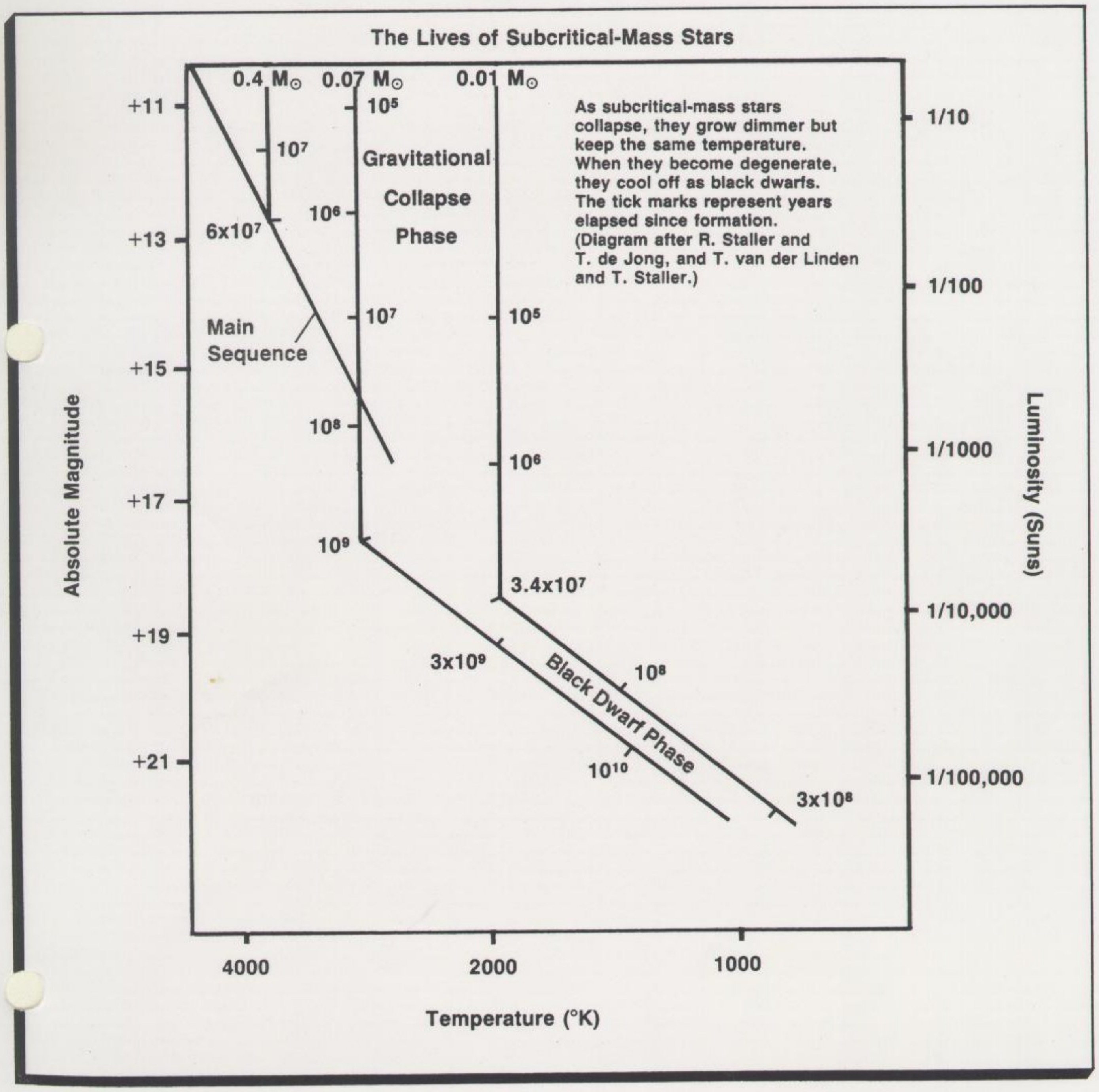
orbital eccentricity, along with a large mass, would argue that a dark companion is a black dwarf. Some astronomers have even speculated that our Sun has a black dwarf companion orbiting far beyond Pluto and perturbing the orbits of Uranus and Neptune. (Pluto's mass is now known to be too small to account for the observed irregularities in the motions of Uranus and especially Neptune.)

Subcritical stars also bear on the question of the initial mass function — a term that describes how many stars formed of any given mass. If the initial mass function constantly increases with decreasing mass, then very-low-mass stars are even more abundant than Main Sequence red dwarfs. If, on the other hand, the initial mass function peaks at some value and afterward decreases with decreasing mass, then very-low-mass stars may be much rarer. A related quantity is the luminosity function — the distribution of stars by absolute magnitude. The luminosity function is small for very bright absolute magnitudes (like our Sun's absolute magnitude of +5), but increases steadily and becomes quite large at the absolute magnitudes of red dwarfs: +9 to +16. The evidence indicates the luminosity function may peak around absolute magnitude +14 and then decline, which suggests that a mass corresponding to this value (roughly 0.15 $M_\odot$) is characteristic or common for stellar formation. Theoretical studies by astrophysicist Joseph Silk show that 0.2 $M_\odot$ may indeed be a characteristic size for stars produced in a nebula. But it is also possible that the luminosity function decreases past absolute magnitude +14 simply



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because that's where telescopes start to miss intrinsically fainter stars — although many astronomers believe the decline sets in before any instrumental limitations are reached.

Some tantalizing evidence exists, however, that there is far more to the solar neighborhood than meets the eye. Although truly cold, dark stars cannot be seen, their collective gravitational influence can be felt by other stars. By analyzing stellar motions, astronomers can deduce the total mass density in the solar neighborhood of the Galaxy. In 1965 Dutch astronomer Jan Oort did just that and concluded that a typical spherical volume of space with a radius of 10 light-years ought to contain 18 $M_\odot$ — though this value has a considerable uncertainty. But adding up all the matter we can detect accounts for little more than half that. In the early 1970s, several astronomers believed they had resolved this "missing mass problem" when they discovered that red dwarfs were far more abundant than previously thought and that the standard luminosity function was seriously in error at faint absolute magnitudes. But a few years later, the truth emerged — these astronomers had made a systematic photometric error that caused them to overestimate red dwarf abundances. Thus the luminosity function seems vindicated at least down to absolute magnitudes +14 or +15. This was good news — but it still left the missing mass problem unresolved.

Is the mass in the solar neighborhood abnormally deficient? And if not, where is it? Oort's estimate of 18 $M_\odot$ per 10 light-year radius is very uncertain, but if it is correct — even roughly — we simply must face the fact that some mass is hiding somewhere in our vicinity. Black holes and neutron stars are possibilities, but they are so rare and exotic that they probably do not affect the overall mass balance of the solar neighborhood very much. Main Sequence red dwarfs still eluding discovery are a more likely possibility, but few astronomers like to pin all their hopes on the long shot that hordes of yet-undiscovered red dwarfs exist nearby. Black dwarfs, on the other hand, could easily make up the deficiency: If there is an average of one black dwarf per two light-year radius, then black dwarfs could account for the solar neighborhood's missing mass.

Aside from such local concerns, the number of black dwarfs in the Milky Way has profound implications for the Galaxy's evolution. Since subcritical mass stars do not burn, the matter locked within them neither changes its form nor escapes into the interstellar medium. More massive stars enrich matter with heavy elements and return it by means of novae, supernovae, and stellar winds to the Galaxy at large. The fewer subcritical stars there are, the faster the galactic material is enriched and returned. In fact, if subcritical stars are very rare, then roughly 40% of the matter in a newborn generation of stars returns to the interstellar medium after a billion years. If, however, very-low-mass stars have as much mass as all others combined, that percentage drops to 20%.

Black dwarfs could affect far more than just the chemical balance of the Galaxy — they could determine the fate of the entire universe. The universe

Cool and nearly invisible, black dwarf stars pose extremely difficult challenges for observational astronomers. Yet if they are as numerous as theory suggests, they have important consequences for the future of our Galaxy — and the universe itself. Painting by Mark Paternostro.

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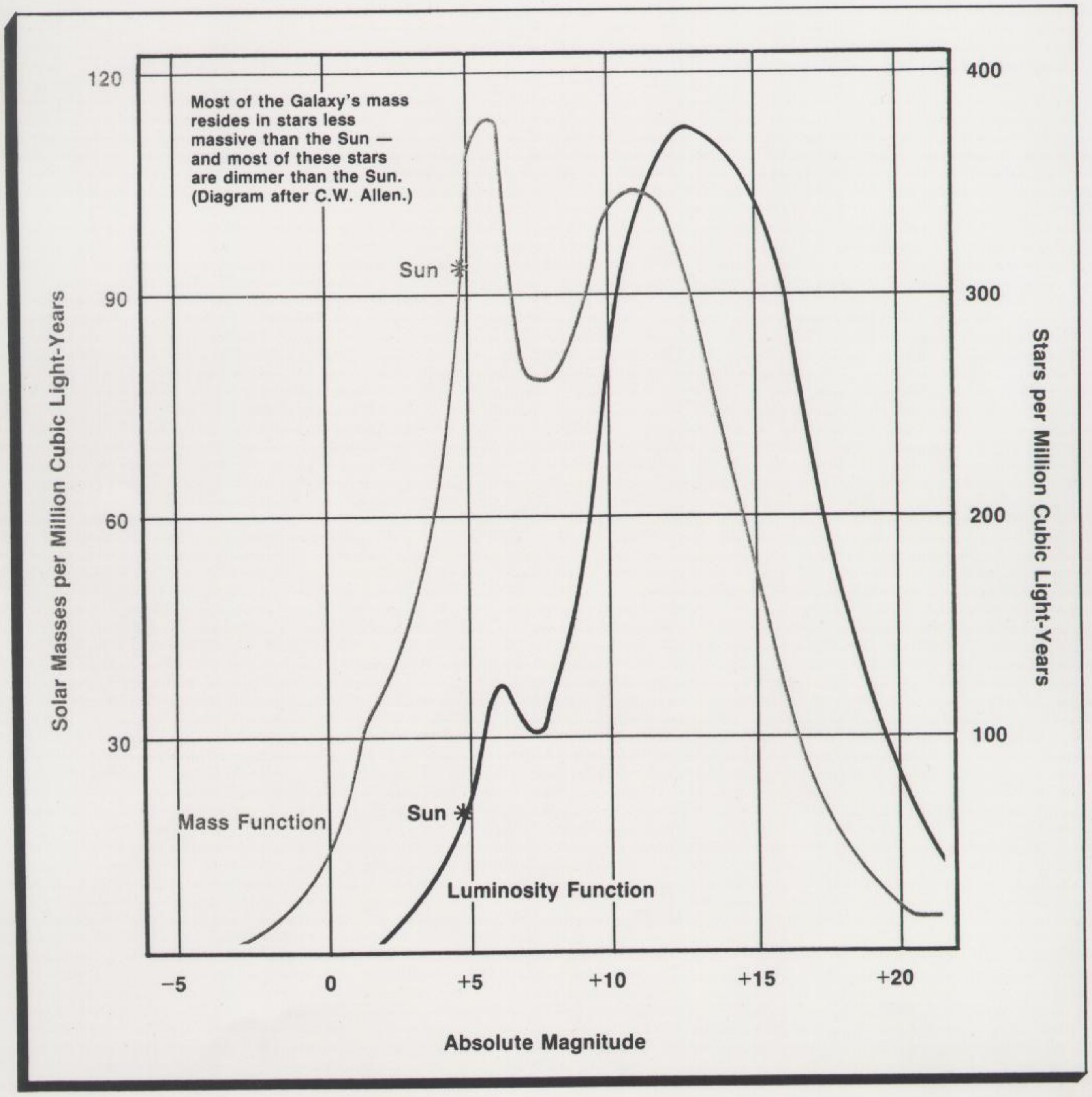
is thought to be expanding from the Big Bang. If it has enough mass, mutual gravitational attraction will reverse the expansion and cause a collapse of the universe. At present, observable matter accounts for only a few percent of the total mass to halt the expansion. Black dwarfs in our Galaxy and others could provide a good deal of the rest, along with black holes, neutron stars, intergalactic gas clouds, and Main Sequence red dwarfs. In fact, because of their low mass, black dwarfs may have preferentially escaped their parent galaxies the way low-weight atoms like hydrogen escaped Earth's atmosphere. Black dwarfs could therefore fill the seemingly empty void between the galaxies. Some astronomers have suggested, furthermore, that the Milky Way's massive corona may consist of many low- and very-low-mass stars.

These little stars, therefore, beset us with enormous mysteries. Stars too small to burn challenge our telescopes to detect them and push observational techniques to the limit. Perhaps the closest such star is only a few light-years away, attended by cold planets immersed in constant darkness and never knowing the difference between night and day. Or is the nearest dark star much closer? Does our Sun have a faithful companion that secretly attends it on its journey around the Galaxy? As always, Nature stands mute, and it is up to us to find out.

Ken Croswell is a graduate student at Harvard University. His most recent feature article was "FG Sagittae: One Piece of the Puzzle," which ran in the October 1983 issue.



AXO OBSERVATIONS OF PLANET X, (P. 170)

Key to Phenomena

- AXOO Introduction
- AXO1 Visual Observations of Planet X
- AXO2 Infrared Observations of Planet X
- AXO3 Radio Observations of Planet X
- AXO0 Introduction

Direct evidence of Planet X is difficult to find. In centuries of planet-hunting, astronomers have discovered many suspicious visual objects, but upon analysis almost all turned out to be asteroids and comets. We say "almost all" because at least one sound observation of what seems to have been a trans-Plutonian planet has never been explained---the so-called Ottawa object. Unfortunately, the Ottawa object has not been seen since 1924, so the situation remains unresolved.

AXO OBSERVATIONS OF PLANET X, (P. 170)

Key to Phenomena — *Continued...*

With the advent of infrared and radio astronomies, a whole new set of potential Planet Xs has appeared. Infrared astronomy has been the most productive so far, discovering many warm objects and extended structures that cannot be associated with anything visual. These warm objects appear in wide-area sky surveys and have not yet been observed with enough precision for astronomers to determine exactly what they are, or even if they are members of the solar system. Since infrared astronomy must be carried out above the earth's atmo-sphere, it may be years before these infrared objects are properly labeled Some, however, are located where there could very well be Planet Xs.

AXO1 Visual Observations of Planet X

Description. The visual or photographic detection of a luminous object with an orbit characteristic of a tenth planet or an MSC (Massive Solar Companion).

Data Evaluation. A single, never-repeated observation of planet X, or at least an object that could be interpreted as a trans-Plutonian planet. Other, similar claims exist in the

Visual Observations of Planet X AXO1 (P 171) *Continued...*

...literature, but they all seem to have been ultimately identified as asteroids, comets, or stars. Rating: 4.

Anomaly Evaluation. The discovery of a substantial tenth planet or an MSC would represent a major astronomical milestone. An MSC would, in effect, make the solar system a binary star system, and place at risk the present theory of solar system formation. Rating: 2.

Possible Explanations. The single object detected could have been an asteroid or comet, just as its several predecessors and followerst

Similar and Related Phenomena. Infrared and radio observations of planet X (AXO2 and AXO3); enigmatic objects (AEO).

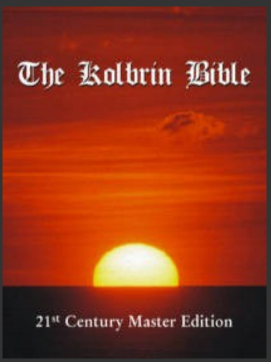
Examples

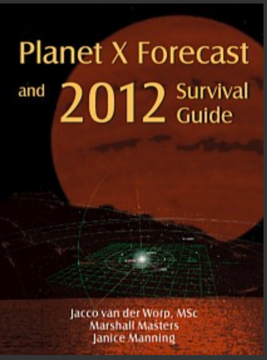
X0. The extensive but negative search for trans-Neptunian planets by Clyde Tombaugh following the discovery of Pluto.

Visual Observations of Planet X AXO1 (P 171) Examples — *Continued...*

"Thus, when the initial excitement and controversy over Pluto's discovery began to subside late in May 1930, young Clyde Tombaugh once again took up his tedious duties at the Lowell Observatory's blink comparator to resume the systematic search for the traps-Neptunian planets that had been so abruptly interrupted by success some three months before. He began where he had left off on that historic February afternoon, by carefully scrutinizing the unblinked portions of the January 23 and 29 Pluto discovery plates of the starrich Gemini region. The task took him a full two weeks.

For the next thirteen years, the photographic search continued, probing the entire sky visible at Flagstaff from 50° south to the North Pole, most of it to magnitudes sixteen and seventeen and in some selected regions out to the eighteenth magnitude. But although nearly 90 million images of some 30 million stars over more than 30, 000 square degrees of the sky were photographed and examined, no more planets were found. Tombaugh felt that the care and thoroughness of this survey justified the conclusion that 'no unknown planets brighter than the





Visual Observations of Planet X AXO1 (P 171) Examples — *Continued...*

...sixteenth magnitude exist and that any planet between magnitude 16 and 17 had a good chance of being discovered. "' (R2) Of course Tombaugh's search did not cover the whole sky, and a distant MSC (Massive Solar Companion) could still be too faint in the visible spectrum to have been picked up. (WRC)

X1. 1924. The Ottawa object. "Again, parenthetically, one of the first things that Tom baugh looked for when he resumed his search was something called the 'Ottawa object,' a short-lived trans-Neptunian planet suspect that was reported on April 22, 1930, at the height of the excitement over Pluto, by R. M. Stewart, thee director of the Dominion Observatory in Ottawa, Canada. Stewart announced that the object had been found during a search for pre-discovery observations of Pluto by C. F. Henroteau and Miss M. S. Burland on plates taken at Ottawa in 1924. He added that the orbit of the object was uncertain, but the two positions of the 1924 plates could 'be satisfied by two circular orbits at trans-Neptunian distances and one at an asteroid distance.'

Visual Observations of Planet X AXO1 (P 171) Examples — *Continued...*

Two weeks later, Crommelin issued a British Astronomical Association Circular, giving a distance of 39.82 a. u. , a longitude of ascending node of 280°29'. 4, and an inclination of 490.7 for the object. On May 8, 1930, he advised Slipher at Flagstaff: 'The Ottawa object may be another trans -Neptunian, but unless more images are found its orbit must remain rather uncertain.' As of 1979 nothing more concerning this object has apparently ever been reported. " (R2) The literature contains other similar sightings, originally supposed to be new, distant planets, but which turned out to be asteroids, comets, or were never seen again. See AEO. (WRC)

References

R1. "Second Trans -Neptunian, "Science News Letter, 17:281, 1930. (XI)

R2. Hoyt, William Graves; "More Planets X?" Planets X and Pluto, Tucson, 1980, p. 248-249. (XO and X

AXO2 Infrared Observations of Planet X (Page 172)

Description. The identification on infrared survey maps of objects of an unidentified nature that are located in positions characteristic of a tenth planet or an MSC (Massive Solar Companion), and/or the extended mass distribution of such an object (satellites, Lagrangian debris, etc.).

Data Evaluation. Several infrared sky surveys have picked up objects that correspond to no known visible astronomical objects, and which could be interpreted as planet Xs or an MSC and its retinue of distributed mass. The data, however, are skimpy and there is no scientific consensus that they actually represent large, unknown solar system objects. Rating: 2.

Anomaly Evaluation. Massive, cold objects in the solar system, especially if they possess their own satellites (planets ?) and debris clouds, are not accounted for in the prevailing scenario of solar system formation and evolution. Rating: 2.

Possible Explanations. Solar system gas clouds.

Similar and Related Phenomena. Visual and radio observations of planet X (AXO1 and AXO3); enigmatic objects (AEO).

AXO2 Infrared Observations of Planet X (Page 172)

Examples

X1. Four-color infrared survey. Abstract. "At the AGU 1978 Midwest Meeting, evidence was presented for a massive stellar companion to the Sun with implications to several aspects of Geodesy. A tentative orbit (116 a. y.) and Ephemeris was presented, as well as an estimate of mass (0. 02 0) for the companion. Since that time, I have studied the observational record in the literature in order to determine if evidence of the body, or satellites of it, already existed. This search has been successful. Using a sensor developed by Hughes Aircraft's Electro-Optical Lab. in the 1960's (including optical engineering performed by the author), the A. F. Geophysics Lab. eventually published in 1977, the results of a four color survey in the infrared (4.2, 11.0, 19.8, and 27.4 micrometers).

AXO2 Infrared Observations of Planet X (Page 172)

Examples — *Continued...*

Thirteen suspects were found whose characteristics suggest they could be planets of the massive stellar companion. These suspects were also found in appropriate positions in the NASA 2 micrometer Sky Survey, published in 1969. The elapsed time between the two surveys (1969 to 1971-1974) has allowed the computation of the mean motion of the massive stellar companion, by averaging the vector advances of all the various planets of it. This has allowed a refinement of the orbit (e = 0.34) and mass (0.018 O). The Hughes Aircraft sensor gathered data between April 3, 1971 and September 11, 1974. Further evidence of geodesic effects by the massive companion have been analyzed and evaluated. " (R1)

X2. The NASA 2-micron survey. "The Two Micron Sky Survey, by Neugebauer and Leighton, 1969, was then examined, confirming properly displaced positions for four of the ten candidates, which tended to confirm their realtiy.

AXO2 Infrared Observations of Planet X (Page 172)

Examples — *Continued...*

Subsequent study of these catalogs and the Supplemental AFGL Catalog issue of July 12, 1977, turned up a total of thirteen doubly observed candidates. These all had angular motions too slow for any known planet or asteroid but too fast for any known star's proper motion. These short arcs are plotted to a rectangular scale in the attached Figure 1 (not reproduced). A composite of all position angles joined end to end gave an overall estimate of mean motion for the SMC M.S.C. satellite system. The observational evidence in the infrared appeared to favor an elliptical orbit of eccentricity 0. 34 and a mass of 0.018 solar masses. " (R2)

X3. Infrared Astronomy Satellite (IRAS) survey. "The latest controversy surrounds an object discovered by IRAS in the constellation Sagittarius. The object's infrared emission shows that it has a temperature of around 230°K. This is too cool for a star yet too hot for a dust cloud.

AXO2 Infrared Observations of Planet X (Page 172)

Examples — *Continued...*

It could be a distant gaseous planet, several times heavier than Jupiter and giving off heat as its own gravity causes it to shrink in size. Whatever it is, say the British astronomers, the Americans have been keeping very quiet about it in recent weeks. " (R4) The existence of such a large, uncondensed object in the solar system would be very startling. (WRC)

X4. General observations. J.P. Bagby on the possibility that the MSC mass may be distributed. "Subsequent to the late 1978

AXO2 Infrared Observations of Planet X (Page 173)

Examples — *Continued...*

...discovery of infrared evidence of satellites of the MSC, L. L. Bagby suggested that the total mass of the MSC might be distributed: (a) amongst the infrared satellites found near it, or (b) amongst the several possible LaGrange points, especially L3 opposite to the MSC which might lie in Pluto's direction at the 1920-1930 epoch. Such a distribution of the mass might account for the long delay in definitive published results by the several groups who have been working from NeptunePluto-Uranus errors alone.

Following the 1981 presentation, a search was made along the orbit plane, using the infrared data, to see if any companion objects in the same orbit could be found. If so, then perhaps a decision as to the proper eccentricity and semi-major axis would follow. Some suspects were found, near R. A. 13h 30m, Dec. -28 degrees; R. A. 03h 20m, Dec. +30 degrees; and R.A. 09h 30m, Dec. 0. 0 degrees. Suspecting these could be objects at or near LaGrange points in the MSC's orbit, unique solutions were derived with this assumption. " (R3)

AXO2 Infrared Observations of Planet X (Page 173)

References

R1. Bagby, John P.; "Observational Evidence for a Massive Stellar Companion to the Sun, " Eos, 61:213, 1980. (XI)

R2. Bagby, John P.; "Reasons for Caution in Arbitrary Rejection of Observations Made during Infrared Sky Surveys: An Opportunity for Discovery of Solar System Satellites, " Paper D-7, Meeting of NATO Scientists and Contractor Personnel, May 20, 1981. (X2)

R3. Bagby, John P.; "Further Speculations on Planet 'X', " Kronos, 9:93, Summer 1984. (X4)

R4. Redfern, Martin, and Henbest, Nigel; "Has IRAS Found a Tenth Planet?" New Scientist, 100:400, 1983. (X3)

'THE SUN AND SOLAR SYSTEM DEBRIS' – BY: WILLIAM R. CORLISS
A CATALOG OF ASTRONOMICAL ANOMALIES'
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ACB13 Cometary Perturbations Suggestive of Planet X

Description. Irregularities in cometary orbits of various kinds, usually undefined in the literature, that are employed to predict the existence and characteristics of Planet X, a body beyond Pluto.

Background. Cometary orbits are notoriously unreliable due not only to nongravitational forces (gas expulsion) but also (possibly) to a dark planetary or defunct stellar body beyond Pluto. Searches for this postulated body or bodies using the telescope have been uniformly negative, but the perturbations of Neptune and many comets, particularly Halley's, seem to tell us that there is something out there. Note that cometary period changes are also dealt with in ACB5.

Data Evaluation. The literature cited in the section rarely specifies the comets used in the analyses or the particular orbital characteristics that have been perturbed. Although this situation is undesirable, the information is probably available somewhere. It seems safe to say that unexplained cometary perturbations really do exist, even though the details are missing in the reports presently on hand. Rating: 2.

Anomaly Evaluation. The anomaly at issue here is not the existence or nonexistence of Planet X but rather the perturbations of the comets. Planet X is just one proposed explanation of these perturbations. The wide ranges of Planet X distances and masses mentioned below assure us that astronomers do not yet have a satisfactory explanation, in Planet X terms, of the cometary perturbations. Since no widely accepted explanation is available, the anomaly rating must be rather high. After all, the perturbations could be due to the inadequacy of the Law of Gravitation or something equally serious. Rating: 2.

Possible Explanations. Planet X or a massive solar companion; nongravitational forces, such as a resisting medium; failure of the Law of Gravitation at great distances.

Similar and Related Phenomena. The residual advances of the planets' perihelions (AHB1, AVB2); changes in cometary periods (ACB5).

Examples

X1. 1931. W.H. Pickering used cometary motions to calculate the orbits of planets P and S, at 75.5 and 48.3 AU, with masses 50 and 5.3 times the earth's, respectively. He relied upon the positions of cometary aphelia to derive the distances. (R6)

X2. 1942. R.S. Richardson, working with the well-known delays in Halley's comet, determined that a delay of half a day could be caused by an earth-sized planet at 36.2 AU. (R1, R6)

X3. 1950. K. Schutte used the orbits of eight periodic comets to predict the existence of a trans-Plutonian planet at 77 AU. (R6)

X4. 1954-1957. H.H. Kritzinger refined Schutte's work, using the same eight comets. One of his predictions was of a new planet at 75.1 AU, with magnitude 10. It was looked for but never found. (R6)

X5. 1972. J. Brady. "Using a computer recently to study disturbances in the motion of Halley's Comet since 295 A.D., Joseph Brady of the University of California Lawrence Livermore Laboratory, predicted that another Planet X should exist beyond the orbit of Pluto. This hypothetical planet would be twice as far from the sun as Neptune and have three times the mass of Saturn or nearly 300 times the mass of Earth---in fact, it would be more massive than all the other planets except Jupiter.

Brady employed the same method used to find Neptune and Pluto. However, instead of looking for irregularities in the orbit of Uranus, he looked for these irregularities in the orbit of Halley's Comet. (This comet regularly returns every 76 years and has been observed since at least 87 B.C.) By carefully choosing just the right mass, position and motion for his new Planet X, Brady found he could reduce the difference between the comet's calculated and observed orbits by 93%." (R3, R4, R2, R6) Brady's Planet X moved in a highly inclined, retrograde orbit. It was looked for but never found. (R6)

X6. 1975. G. Chebotarev made a mathematical analysis of cometary orbits observed in the prior century, claiming they indicated the presence of Planet Xs at 54 and

100 AU. (R6)

X7. 1978. J. Kirk explored the effect of the postulated companion star to the sun. His conclusion was that the orbits of new comets are so close to being parabolic that there cannot be a solar companion in bound orbit about the sun. (R5)

X8. 1981. P.K. Seidelmann et al. "The authors conclude that some unmodelled force is acting on the outer planets. Observations of six long-period comets, which have had more than one apparition, show that these too are being perturbed by an unmodelled force perpendicular to their orbital plane. The well known non-gravitational force acting on comets has no component in this direction. All these comets have aphelia beyond Neptune.

The cause of the force is unknown. That a Planet X beyond Pluto is exerting a gravitational effect is a possibility but the authors stress that the long and unsuccessful photographic search made by Clyde Tombaugh makes its existence unlikely. If, for example, Planet X was as massive as Jupiter, Tombaugh concluded that he would have found it if it were closer than 470 AU. Also, this phantom 'Planet X' does not seem to have a measurable effect on the orbits of new comets. These comets, which have just been 'bumped' out of the Oort cloud by a passing star, seem to have near perfect parabolic orbits and there is no anisotropy in their major axis distribution. Furthermore, Planet X does not seem to affect the plane of symmetry of the Solar System. This seems to be dominated by Jupiter." (R7)

X9. 1985. A.H. Delsemme. The orbits of 126 young comets reflect the gravitational influence of a massive body with a mass 10-90 times that of Jupiter, orbiting the sun ever every 5-50 million years. Called Nemesis in the literature of the 1985 period, it is a dark, massive solar companion. (R8)

References

R1. "New Planet May Be Added to the Sun's Family of Nine," Science News Letter, 41:361, 1942. (X2)

R2. "Cometary Evidence of a Planet beyond Pluto," Science News, 101:293, 1972. (X5)

R3. Weaver, Wm. Bruce; "In Search of Planet X," Astronomy, 1:17, August 1973. (X5)

R4. "Does Planet X Exist?" Sky and Telescope, 45:22, 1973. (X5)

R5. Kirk, J.; "On Companions and Comets," Nature, 274:667, 1978. (X7)

R6. Hoyt, William Graves; "More Planets X?' Planets X and Pluto, Tucson, 1980. (X1-X6)

R7. Hughes, David W.; "Planet X: Is It Necessary?" Nature, 291:613, 1981. (X8)

R8. Cowen, Robert C.; "The Mystery of the 'Death Star'," Baltimore Sun, August 11, 1985, p. 5E. (X9)

ACB14 Rapid Attrition of the Oort Cloud by Molecular Clouds

Description. The calculated rapid demise of an Oort Cloud of comets due to the sweeping influence of giant molecular clouds from interstellar space. Such molecular clouds are common, and the solar system almost certainly encountered several during its lifetime. Thus, the Oort Cloud, if it ever existed, may have had a very short lifetime.

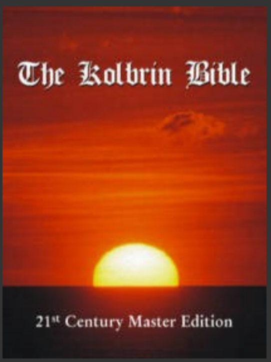
Data Evaluation. The constituents of giant molecular clouds and their densities are not known with precision. The parameters of the Oort Cloud must be hypothesized, since it cannot be observed directly. The computed attrition rate is therefore only approximate. Rating: 3.

Anomaly Evaluation. The Oort Cloud hypothesis has the cometary shell forming at roughly the same time as the solar system and surviving with minor attrition to the present day. A rapid sweeping action by molecular clouds would cast doubt on the Oort Cloud theory. Rating: 2.

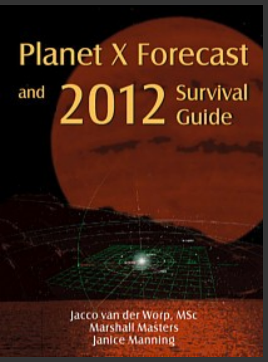
The Jenner Files:

Irrefutable Planet X Evidence

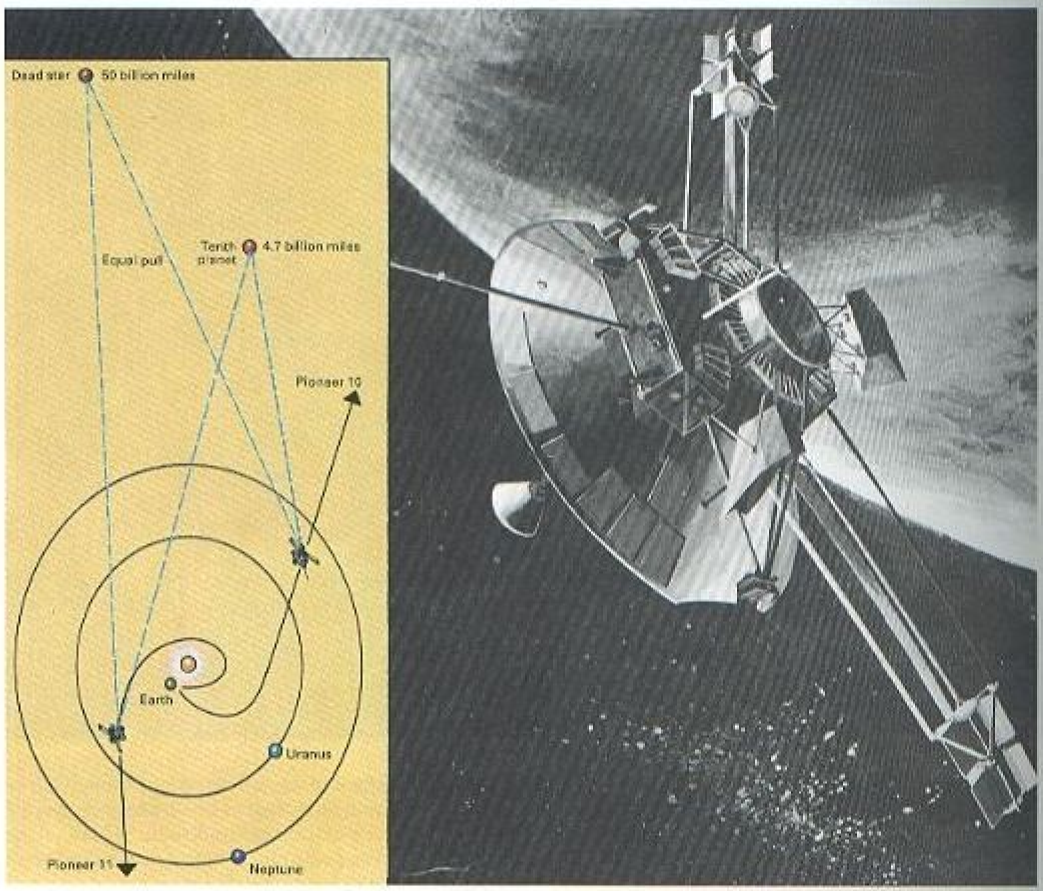
"Greg Jenner spent decades connecting the dots for this book. Now you can do the same, in a single evening!" *—Marshall Masters*

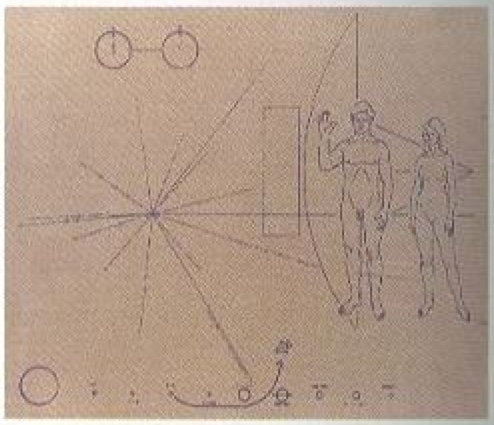


"The Kolbrin Bible is the Rosetta Stone of Planet X!"*—Greg Jenner*



"Required reading for those who get it and want to live through it."*—Echan Deravy, Solar Code*





Above: Pioneer 10 became the first craft to pass into interstellar space in 1983. The diagram (inset) shows the path of the two Pioneer probes.
Right: The pictorial plaque carried by Pioneer 10 contains information about Earth and humanity.

rockets to keep the spacecraft attitude correct while the main retro-rocket slowed the craft down. This was then ejected and the vernier rockets took the spacecraft down to a soft landing. An essential feature of this technique is an automatic onboard controller linked to a radar altimeter and velocity sensor working on the DOPPLER principle, which enables the craft to know how high above the surface it is and how fast it is moving. (Guidance from Earth would be difficult because of the two and a half second delay in the round trip of a radio signal between Moon, Earth and Moon.) This system is now standard for soft landing space probes.

Another device was the crewless lunar rover, the Lunokhod series placed on the Moon by the U.S.S.R. These were carried aboard soft landing craft and moved about the Moon's surface under the control of a driver on Earth. The vehicles were equipped with

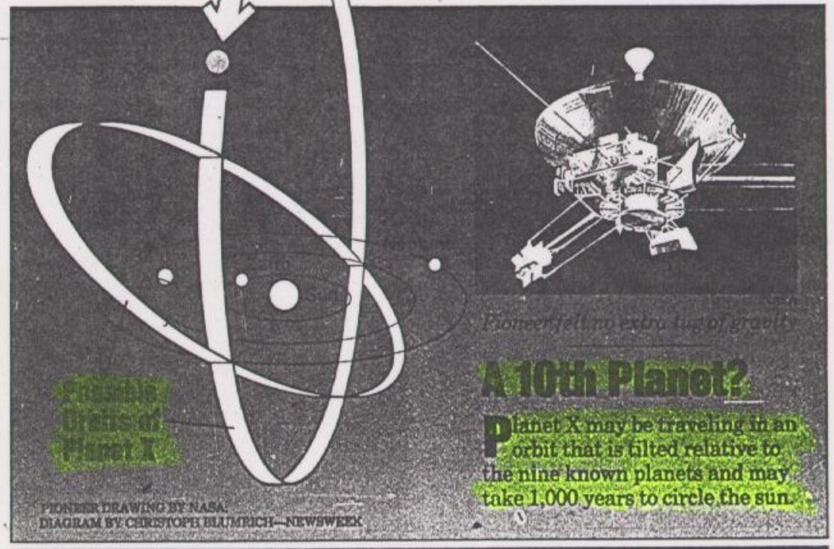
SPACE

The Search for Planet X

Answering old riddles?

NASA held a press conference at its Ames Research Center in California last week to make a rather strange announcement: an eccentric 10th planet may—or may not—be orbiting the sun. John Anderson, a NASA research scientist who was the principal speaker, has a hunch Planet X is out there, though nowhere near the other nine. If he is right, two of the most intriguing puzzles of space science might be solved: what caused mysterious irregularities in the orbits of Uranus and Neptune during the 19th century? And what killed off the dinosaurs 26 million years ago?

Anderson bases his belief in Planet X on a *lack* of evidence gleaned from the flights of the two Pioneer spacecraft, now heading into the farthest reaches of the solar system. Back in the last century astronomers noticed that something was causing odd changes in the orbits of Uranus and Neptune. One possible explanation was the tug of gravity from an undetected planet. But if Planet X cruised in a typical orbit, it should have exerted its gravitational tug on the tiny, free-floating Pioneers. That didn't happen.



A 10th Planet?

Planet X may be traveling in an orbit that is tilted relative to the nine known planets and may take 1,000 years to circle the sun.

Why? Anderson and Kenneth Seidelmann, an astronomer at the Naval Observatory in Washington, D.C., searched for an explanation. After double-checking they concluded that the 19th-century records were accurate. They calculated that a distant planet—five times as heavy as Earth—traveling in a very elongated elliptical orbit, possibly perpendicular to the orbits of the known planets, could have caused the changes the 19th-century astronomers saw. By now, however, Planet X would be too far away in its peculiar orbit to affect Neptune or Uranus or to have tugged the Pioneer spacecraft out of their trajectories. Their theory neatly supported observations by astronomers that the orbits of Uranus and Neptune had stopped being perturbed in the early 20th century.

It also matches Daniel Whitmire's explanation for the extinction of the dinosaurs. The University of Southwestern Louisiana astrophysicist envisions a cosmic catastrophe: Planet X's orbit could have passed through the ring of comets surrounding the solar system. When that happened, comets pulled by the planet's gravity could have careened out of their solar orbits, some smashing into the Earth. Dust thrown into the atmosphere would have triggered vast changes in climate, dooming the dinosaurs. Other astronomers believe it wasn't Planet X but a distant, undiscovered companion star to the sun—sometimes called Nemesis or the "death star"—that sent comets caroming toward Earth. There's no more evidence for that, however, than for the existence of Planet X.

Unriddling this puzzle is far from easy. The standard technique is to compare a photograph of a section of the night sky to another taken several weeks later. The stars stay put; but a planet will have moved slightly. The toughest problem, as Whitmire sees it, is that no one really knows where to look. If the question isn't solved sooner, astronomers in the year 2600 might tackle the issue; that's about when Planet X should be causing perturbations in Neptune's orbit again.

WILLIAM D. MARBACH *with* MICHAEL D. CANTOR

FAMILY

The Divorce Game: Slippery Numbers

Is Divorce Court the sequel to the Newlywed Game for half of all married couples? Last week pollster Louis Harris challenged that frequently cited prediction. By dividing Census Bureau figures on divorced people with the number of people who are married, widowed or divorced (the "ever-married," in demographers' parlance), Harris concluded that only one out of eight—not one out of two—marriages will fail. He claimed that many so-called experts misread data: "People compare the 2.5 million new marriages each year with the 1.1 million divorces to conclude that roughly half of all marriages are breaking up. This is statistical nonsense."

But others called Harris's one-in-eight prediction nonsense. Census Bureau demographer Arthur Norton contended that no demographer would use simple division to make projections. "Harris's study flies in the face of all the research," he said. In interpreting the data, it's important to note *when* a couple married, he pointed out. Norton has predicted that one out of every two marriages begun since the mid-1970s will end in divorce. Age is also important. Norton and his colleague Jeanne Moorman expect that 60 percent of ever-married women who were between 30 and 39 in 1985 will divorce at least once while only 24 percent of ever-married women then in their 50s will divorce.

Harris stood by his projections, claiming that the institution of marriage is stronger than people think. Government demographers replied that while there has been a slight decline in divorces recently, the breakup rate for younger people was still high and they don't expect dramatic changes soon.

The Jenner Files:

Irrefutable Planet X Evidence

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THE LOCATION OF PLANET X

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Received 17 May 1988; revised 12 July 1988

ABSTRACT

Planet X, if it exists at all, is most likely to be found, at present, in the region of Scorpius, with a considerably lesser likelihood that it is in Taurus.

In 1930, Tombaugh found the planet Pluto. This was the result of a systematic search initiated at Lowell Observatory as the result of predictions made by Lowell as to the position and nature of a supposed additional planet in our solar system. At the time, Pluto was hailed as the object of that prediction, even though there were anomalies in its appearance and orbit evident right from the time of its discovery. Since then, these problems have only become more serious, and the discovery of its satellite in 1978 revealed a mass of Pluto that could not have caused any of the perturbations in the orbits of Uranus and Neptune used to predict the existence of a ninth planet. For a complete review of the discovery of Pluto and the developments leading up to the suspicion of the existence of a tenth planet, see Seidelmann and Harrington (1988).

The motions of Uranus and Neptune cannot be adequately represented within the present gravitational model of the solar system. Pluto cannot have any detectable effect on these two planets. There is therefore a good possibility that there is at least one undetected planet in our solar system, and it is now possible to set some constraints on where that planet might be.

The observations used in this study were taken from compilations of all positional determinations available through 1982 for each planet of interest. These observations are quite varied in nature and source and include both visual and photographic determinations. The Uranus observations go back to 1833 and the Neptune ones to 1846. These compilations were supplied by the Nautical Almanac Office of the U. S. Naval Observatory. They consist of observed positions of Uranus and Neptune, along with residuals in right ascension and declination from positions computed from DE200 (Standish 1982a,b). The residuals were first converted to residuals in ecliptic longitude (great circle) and latitude. As a statistical approximation, this is not correct, since these data are not statistically independent. However, for the present analysis this makes no difference, and it greatly facilitates the subsequent comparison with numerical simulations.

These residuals were then combined into seasonal normal points, producing average geocentric residuals spaced slightly more than a year apart. These residuals were then assumed to be adequate representations of the equivalent heliocentric average residuals for the observed oppositions. There are usually enough observations per opposition, with enough balance pre- and post-opposition, that the small systematic errors within each observation should tend to cancel out in the mean. The exception would be that, in the mean, heliocentric residuals should be, at most, a few percent smaller in magnitude, an effect that is well below the noise level within each normal point. In any case, these short-period differences do not affect the long-period effects being sought. Finally, a weight was assigned to each normal point. Weights based upon the rms scatter within each normal would give the bulk of the weight to the observations after about 1920, and therefore on modern transit-circle observations. However, it is important to give enough weight to early observations to give them some significance in a solution for long-period effects. Therefore, the weights were based merely on the square root of the number of observations per normal. A few tests indicated that this consideration is not significant for the final results.

The item of interest for the present analysis is the perturbation in the orbit of a known planet, produced by the presence of an unknown Planet X. (X can be thought of as either representing the unknown or the number 10.) Hence, the equations of motion are cast in the form of the motions of the residuals in rectangular coordinates. For numerical work, this is known as Encke's method, and the description followed here comes from Brouwer and Clemence (1961). The method relies on the fact that it is being applied only to the orbits of Uranus and Neptune. These planets are sufficiently distant, move sufficiently slowly, and are perturbed sufficiently little that all vectors representing planetary positions, whether known or unknown but assumed, as they appear in the derivatives of the perturbations, can be represented by approximate vectors. For assumed Planet X orbits, two-body motion is assumed. For Uranus and Neptune, the low-precision formulas as given by Van Flandern and Pulkkinen (1979) are employed.

Additional assumptions are that the perturbations are sufficiently small that expansions in them are only required through first order and that the mass of the perturbed planet need not be included in the solar gravitational constant representing the principal term in the acceleration of the perturbation (both of these have been numerically verified). The result of this development is a set of relatively simple equations of motion that can be integrated very quickly for a given orbit of Planet X. A reintegration of the entire outer solar system is not needed for each test case and, indeed, only the positions of the perturbing and the perturbed planets (the perturber and the perturbee) are required.

To be specific, let ξ be the vector of perturbations of an observed planet, caused by Planet X, from the vector $\mathbf{r}$ of the predicted position of the observed planet, based on the known gravitational model of the solar system (i.e., the actual vector of observations is $\mathbf{r} + \xi$). The vector $\mathbf{r}$ is approximated as described above. Let $\mathbf{r}_X$ be the position vector of Planet X. Let μ be the gravitational constant of the Sun and μ_X be that of Planet X. The equation of motion for the perturbation vector can therefore be written as follows:

$$\ddot{\xi} = \frac{\mu}{|\mathbf{r}|^3}\left(\frac{3\mathbf{r}\cdot\xi}{|\mathbf{r}|^2}\mathbf{r} - \xi\right) + \mu_X\left(\frac{\mathbf{r}_X - \mathbf{r}}{|\mathbf{r}_X - \mathbf{r}|^3} - \frac{\mathbf{r}_X}{|\mathbf{r}_X|^3}\right).$$

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In 1930, Tombaugh found the planet Pluto. This was the result of a systematic search initiated at Lowell Observatory as the result of predictions made by Lowell as to the position and nature of a supposed additional planet in our solar system. At the time, Pluto was hailed as the object of that prediction, even though there were anomalies in its appearance and orbit evident right from the time of its discovery. Since then, these problems have only become more serious, and the discovery of its satellite in 1978 revealed a mass of Pluto that could not have caused any of the perturbations in the orbits of Uranus and Neptune used to predict the existence of a ninth planet. For a complete review of the discovery of Pluto and the developments leading up to the suspicion of the existence of a tenth planet, see Seidelmann and Harrington (1988).

The motions of Uranus and Neptune cannot be adequately represented within the present gravitational model of the solar system. Pluto cannot have any detectable effect on these two planets. There is therefore a good possibility that there is at least one undetected planet in our solar system, and it is now possible to set some constraints on where that planet might be.

The observations used in this study were taken from compilations of all positional determinations available through 1982 for each planet of interest. These observations are quite varied in nature and source and include both visual and photographic determinations. The Uranus observations go back to 1833 and the Neptune ones to 1846. These compilations were supplied by the Nautical Almanac Office of the U. S. Naval Observatory. They consist of observed positions of Uranus and Neptune, along with residuals in right ascension and declination from positions computed from DE200 (Standish 1982a,b). The residuals were first converted to residuals in ecliptic longitude (great circle) and latitude. As a statistical approximation, this is not correct, since these data are not statistically independent. However, for the present analysis this makes no difference, and it greatly facilitates the subsequent comparison with numerical simulations.

These residuals were then combined into seasonal normal points, producing average geocentric residuals spaced slightly more than a year apart. These residuals were then assumed to be adequate representations of the equivalent heliocentric average residuals for the observed oppositions. There are usually enough observations per opposition, with enough balance pre- and post-opposition, that the small systematic errors within each observation should tend to cancel out in the mean. The exception would be that, in the mean, heliocentric residuals should be, at most, a few percent smaller in magnitude, an effect that is well below the noise level within each normal point. In any case, these short-period differences do not affect the long-period effects being sought. Finally, a weight was assigned to each normal point. Weights based upon the rms scatter within each normal would give the bulk of the weight to the observations after about 1920, and therefore on modern transit-circle observations. However, it is important to give enough weight to early observations to give them some significance in a solution for long-period effects. Therefore, the weights were based merely on the square root of the number of observations per normal. A few tests indicated that this consideration is not significant for the final results.

The item of interest for the present analysis is the perturbation in the orbit of a known planet, produced by the presence of an unknown Planet X. (X can be thought of as either representing the unknown or the number 10.) Hence, the equations of motion are cast in the form of the motions of the residuals in rectangular coordinates. For numerical work, this is known as Encke's method, and the description followed here comes from Brouwer and Clemence (1961). The method relies on the fact that it is being applied only to the orbits of Uranus and Neptune. These planets are sufficiently distant, move sufficiently slowly, and are perturbed sufficiently little that all vectors representing planetary positions, whether known or unknown but assumed, as they appear in the derivatives of the perturbations, can be represented by approximate vectors. For assumed Planet X orbits, two-body motion is assumed. For Uranus and Neptune, the low-precision formulas as given by Van Flandern and Pulkkinen (1979) are employed.

Additional assumptions are that the perturbations are sufficiently small that expansions in them are only required through first order and that the mass of the perturbed planet need not be included in the solar gravitational constant representing the principal term in the acceleration of the perturbation (both of these have been numerically verified). The result of this development is a set of relatively simple equations of motion that can be integrated very quickly for a given orbit of Planet X. A reintegration of the entire outer solar system is not needed for each test case and, indeed, only the positions of the perturbing and the perturbed planets (the perturber and the perturbee) are required.

To be specific, let $\boldsymbol{\xi}$ be the vector of perturbations of an observed planet, caused by Planet X, from the vector $\mathbf{r}$ of the predicted position of the observed planet, based on the known gravitational model of the solar system (i.e., the actual vector of observations is $\mathbf{r} + \boldsymbol{\xi}$). The vector $\mathbf{r}$ is approximated as described above. Let $\mathbf{r}_X$ be the position vector of Planet X. Let μ be the gravitational constant of the Sun and μ_X be that of Planet X. The equation of motion for the perturbation vector can therefore be written as follows:

$$\ddot{\boldsymbol{\xi}} = \frac{\mu}{|\mathbf{r}|^3}\left(\frac{3\mathbf{r}\cdot\boldsymbol{\xi}}{|\mathbf{r}|^2}\,\mathbf{r} - \boldsymbol{\xi}\right) + \mu_X\left(\frac{\mathbf{r}_X - \mathbf{r}}{|\mathbf{r}_X - \mathbf{r}|^3} - \frac{\mathbf{r}_X}{|\mathbf{r}_X|^3}\right).$$

Where Is Planet X?

Mark Littmann, Baltimore, Maryland

URANUS was misbehaving. For 60 years after the planet's discovery by William Herschel in 1781, its orbital motion — first too fast, then too slow — seemed to defy Newton's law of gravity.

Theories were launched and sunk. Vortices between the planets? A flaw in the law of gravity? Some scientists suspected that this irregular motion was caused by an unknown planet beyond Uranus. Independently, John Couch Adams in England and Urbain Le Verrier in France developed a new mathematical analysis to force the perturbed motion of Uranus to reveal the existence, even the position, of an outlying planet. They succeeded brilliantly, but senior astronomers around them ignored or bungled the chance to find a new planet.

Finally, in frustration, Le Verrier contacted Johann Galle, an assistant at the Berlin Observatory. On September 23, 1846, Galle and graduate student Heinrich d'Arrest found the culprit, Neptune, almost exactly where Le Verrier (and Adams) had predicted. Their search took less than an hour. The discovery of Neptune was the most spectacular confirmation of Newton's concept of universal gravitation since the law was published in 1687.

The existence of Neptune explained almost all the problems in the motion of Uranus — almost, but not quite. There remained unexplained "residuals" in the movement of Uranus, even though they were less than 2 percent of what had led Adams and Le Verrier to Neptune. Nevertheless, a few astronomers used these tiny irregularities to postulate the existence of a ninth planet beyond Neptune. Percival Lowell and William H. Pickering, working separately in the United States, found themselves lured ever onward by this tantalizing vision. After a 10-year observational and mathematical search for "Planet X" without success, Lowell died in 1916, in part of disappointment.

However, the observatory Lowell founded in Flagstaff, Arizona, continued to operate. In 1929 the Lowell family provided a 13-inch photographic refractor for a renewed search. To resume the quest, the observatory hired a 22-year-old Kansas farm boy with only a high-school education. Less than a year into the search, on February 18, 1930, Clyde Tombaugh found Pluto within 6° of where Lowell and Pickering had predicted it would be. Shades of Adams and Le Verrier!

After discovering Pluto in 1930, Clyde Tombaugh continued combing the sky for additional faint outer planets. By 1943 he had covered essentially the entire region from declination −50° to +50°, looking for objects as faint as 16th or 17th magnitude. During this project he spent 7,000 hours examining photographic plates on a blink comparator. Tombaugh now lives in Mesilla Park, New Mexico, and is seen here at the eyepiece of his homemade 16-inch reflector. New Mexico State University photograph by Jack Dixen.

But there was trouble. Pluto was tiny and showed no disk to telescopes of that day. In fact, it showed no certain disk even when the Palomar 200-inch telescope went into operation. Pluto failed to occult stars it passed. It had to be smaller even than Mercury — the smallest planet in the solar system.

How could such a tiny object cause measurable perturbations in the motion of Uranus, which is never closer to Pluto than a billion miles, more than 10 times the Earth's distance from the Sun? The discovery of Pluto must have been an accident — or, more accurately, the result of Tombaugh's intelligent and extremely careful search.

Then, in 1978, James Christy at the U. S. Naval Observatory discovered that Pluto has a moon. His colleague Robert S. Harrington quickly used that satellite, Charon, to calculate Pluto's mass. The ninth planet had only about 20 percent the mass of Earth's Moon. But if Pluto wasn't massive enough to cause irregularities in the motion of Uranus and Neptune, what *was* causing those discrepancies? Had Planet X been missed? Was there yet an undiscovered planet in the solar system?

VAN FLANDERN, HARRINGTON: CATACLYSM AT NEPTUNE

The search for a 10th planet based on the residuals of Uranus and Neptune continues to this day as a part-time activity practiced independently by a small but tenacious group of astronomers who believe that these residuals are an essential clue to the problem.

The unruliness of Uranus and Neptune nagged at U. S. Naval Observatory astronomer Thomas A. Van Flandern. Orbits calculated for Neptune worked briefly, but after 10 years the planet's predicted positions would be noticeably in error. A calculated orbit for Uranus would fit for one whole circuit of that planet but, maddeningly, would fail for the previous or subsequent revolution.

Van Flandern suggested the idea of a

10th planet to Robert Harrington in 1976. Harrington was skeptical at first, but when the discovery of Charon allowed him to calculate the mass of Pluto, he became convinced that Pluto could not be the perturbing force.

Because its path crosses inside the orbit of Neptune, Pluto was once thought to be an escaped moon of Neptune. The idea had been proposed independently by Issei Yamamoto of Japan in 1934 and Raymond A. Lyttleton of England in 1936. Pluto and Neptune's giant moon Triton had passed too close to one another, they said, and Pluto had been hurled out of the Neptunian system. The encounter had also reversed Triton's direction of travel. That idea was now dead. Pluto has too little mass to reverse the flight of Triton.

Yet here was Triton — the only large retrograde moon in the solar system. Here was Pluto, even smaller than Triton, with an orbit that crosses Neptune's. Since these anomalies cannot be caused by interactions within the Neptunian system, can they have come from outside — in the form of an intruder planet? Are the lingering irregularities in the motion of Uranus the "gravity prints" of an unlicensed orbital mechanic on the rampage?

Off to the computer went Van Flandern and Harrington. Hypothetical intruder planets of different sizes began hurtling through the simulated Neptune system at varying distances, angles, and speeds. A mug shot emerged: a planet 2 to 5 times the mass of Earth in a highly inclined and elliptical orbit, 50 to 100 astronomical units (a.u.) from the Sun, with a revolution period of about 800 years. In one brief visit long ago, such a planet could have reversed the motion of Triton and cast the moon Pluto out of the Neptune family onto a planetary orbit of its own.

Charon was perhaps another moon of Neptune, expelled with Pluto so that they captured one another. Or perhaps the tidal strain of the intruder planet caused Pluto to break in two, with Charon the smaller fragment.

Harrington and Van Flandern felt that Pluto and Charon, by their inclined, eccentric path, hinted at their past by returning four times a millennium to a position near the scene of the crime — the place from which they were kidnapped and abandoned, the place of their birth.

As to mounting a search for a 10th planet, Van Flandern considers it premature. Better data and more mathematical analysis are needed to pinpoint where it might be found.

Harrington, however, hopes to locate the suspected planet by brute force — supplying a computer with thousands of orbits to crunch to expose those that might be possible. Since 1979 he has made six searches for Planet X, most recently with the 8-inch double astrograph at the Black Birch site in New Zealand. After examining all the plates on a blink comparator, he has, in his words, "nothing to show for my efforts."

Harrington thinks that the irregularities in the motions of Uranus and Neptune are real but admits they are slight. Imagine,

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I spent many years
of my life blinking
photographic plates, and
I know how easy it is
to miss something.
— Charles Kowal

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he says, observing from Washington, D. C., and identifying a drunk coming out of a Baltimore bar by his stagger. But he is encouraged to keep hunting by the computer simulation he and Van Flandern performed that found that a single interloper could account for the present motions of Triton and Pluto.

Harrington has just published a new calculation for a 10th planet. He believes it has a mass of 4 Earths and orbits the Sun at 2½ times the distance of Pluto on a very eccentric and inclined path. Currently it should be found in the region of Scorpius, with a magnitude of 14.

If Harrington finds this object, he has a name ready: Humphrey. The name was inspired by "Humphrey the Camel," an off-color song of the 1960's. But Humphrey isn't exactly a traditional Roman or Greek name. "Well," says Harrington, "I considered Zorba." Searching for a 10th planet requires commitment, he feels, but it doesn't pay to take yourself too seriously.

POWELL: THE OLD-FASHIONED WAY

Harrington and Van Flandern are not alone in their efforts to find a 10th planet by squeezing the residuals of Uranus. Doggedly but good-naturedly pursuing that course is Conley Powell, an aerospace engineer for Teledyne-Brown Engineering in Huntsville, Alabama. Unlike Harrington and Van Flandern, he discards the Neptune residuals from consideration because Neptune has not yet completed one full revolution since its discovery. Its orbit, he feels, is not yet known with enough precision. In the tradition of Adams, Le Verrier, and Lowell, Powell analyzes the discrepancies between the predicted and actual positions of Uranus to determine by mathematics the position of a 10th planet.

Because observations of Uranus after 1910 provide much more positional accuracy than early ones, Powell assigns less weight to early observations and more weight to those made in the 20th century.

The Planet X Powell derives is smaller, closer, and brighter than expected. It has 35 percent of Earth's mass and orbits the Sun a little closer than Pluto. In many respects, Powell's planet closely resembles an oversize Pluto. It too spends part of its circuit inside the orbit of Neptune. Powell is fascinated by the similarities between his new prediction and the final predictions for a ninth planet by Lowell and Pickering.

This 10th planet, Powell finds, should now be in Virgo (near where Pluto currently lies) and comparatively bright at magnitude 14. "It's hard to see how Tombaugh could have missed it," muses Powell. "Either Tombaugh is mistaken in thinking that he could not have missed a planet brighter than 16th magnitude, or my calculations are mistaken."

If his planet is found, Powell would like to name it Persephone, after Pluto's wife. Even if his calculations lead to no planet discovery, he still believes that the Uranus residuals are significant. Perhaps there are two undiscovered planets out there whose gravitational effects confuse matters.

GOMES AND FERRAZ-MELLO: A THIRD OPINION

The small mass of Pluto also prompted Rodney S. Gomes and Sylvio Ferraz-Mello of Brazil to examine the residuals of Uranus and Neptune for evidence of a 10th planet. They found plausible orbits at several different distances, all with very small inclinations to the ecliptic. One nearly circular orbit puts the undiscovered planet 45 a.u. from the Sun with about half the mass of Earth. Another possible orbit is as eccentric as Pluto's and places Planet X — with three times Earth's mass — at 80 a.u.

Gomes believes that the most likely position for Planet X is in Cancer or Gemini, nearly the opposite part of the sky from Harrington's favored location and about 70° from Powell's choice. But he and Ferraz-Mello do not think their present results justify a search. They can't specify an exact location. Tombaugh's intensive full-sky search covered this region without finding anything. The Uranus residuals might, they believe, be ex-

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The Jenner Files:

Irrefutable Planet X Evidence

plained away as systematic errors. Even if the residuals are real, the culprit could be uneven distribution of matter in the outer solar system rather than a planet.

ANDERSON: "NO" MEANS "YES"

In 1987, an unlikely new proponent of a 10th planet attracted much attention. John Anderson at the Jet Propulsion Laboratory, was working with NASA's Pioneer 10 and 11 spacecraft. Both craft are now headed out of the solar system in nearly opposite directions. Pioneer 10 is already beyond the orbits of the planets.

Anderson tracked the departing probes by their radio signals for five years to see if either was deflected from its course by gravity waves moving across the cosmos or by the pull of a trans-Plutonian planet. But neither craft exhibited any sign of unusual perturbation. Anderson therefore concludes that a 10th planet most likely does exist — a positive conclusion from what seems like negative evidence!

Two years earlier, the interpretation of this data by Anderson was negative: "A three-year analysis of radio tracking data from the Pioneer 10 spacecraft . . . fails to reveal the presence of Planet X."

The data have not changed, but Anderson now believes in the existence of a 10th planet based on the slight unpredictabilities in the motion of the outer planets. The *lack* of perturbations in the Pioneers therefore provides information about the unseen planet's path.

Planet X, he concludes, was disturbing Uranus and Neptune before and during the 19th century but is now too far away on its highly elliptical and inclined orbit for its gravitational effects to be noticeable on the planets or even on the two tiny, distant Pioneer craft. Its perturbations on the outer planets won't be detected again until about the year 2600.

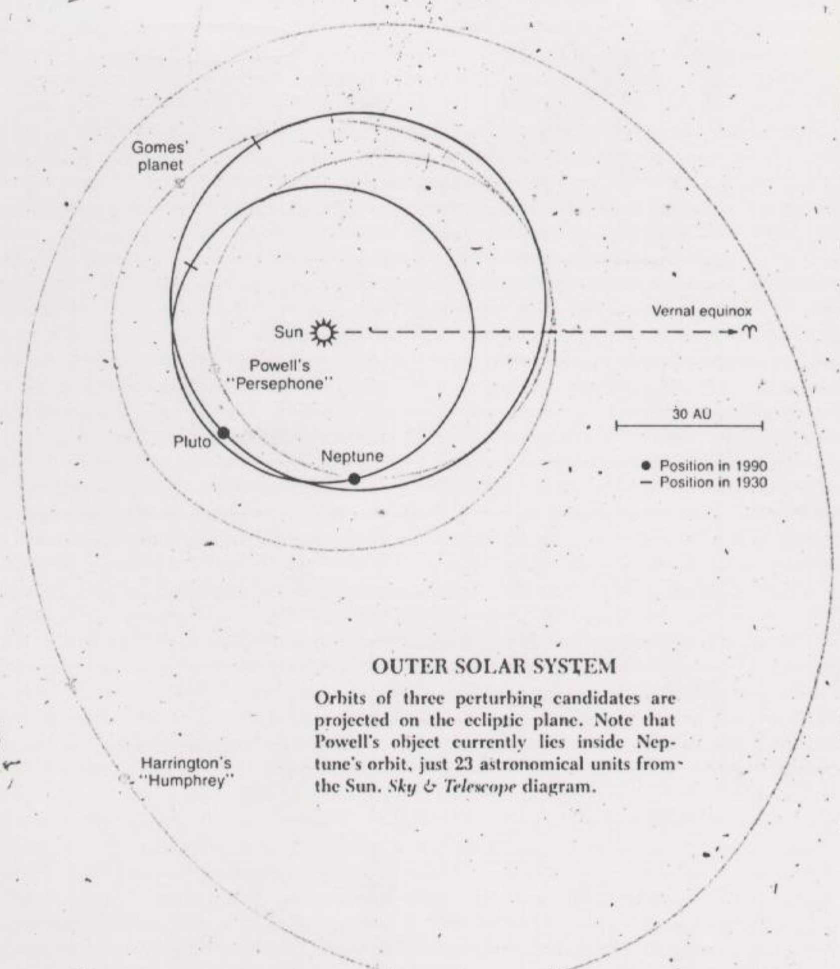
Anderson puts the orbital period of Planet X at 700 to 1,000 years and its mass at about 5 Earths so that, at perihelion, it could cause the planetary perturbations recognized in the U. S. Naval Observatory data.

For the time being this would-be planet has left us few, if any, clues as to where in the sky to search for it. Anderson hopes that, as Voyager 1 and 2 sail out beyond the planets, their deflections will pin down the location of Planet X.

WHERE IS PLANET X?

	Harrington	*Powell**	*Gomes†*	*Anderson*
Mass (Earth = 1)	4	0.35	0.49	5
Mean Dist. (a.u.)	101.2	34.6	44	79-100
Period (years)	1,019	204	292	700-1,000
Eccentricity	0.411	0.335	0.05	substantial
Inclination (°)	32.4	5.43	low	high
Magnitude	14	14	14-15	?
Probable location	Scorpius	Virgo	Cancer?	?

*Newest calculations (not previously published).
†The "best fit" among many solutions is listed; Gomes' object may lie within 50° of Cancer.



OUTER SOLAR SYSTEM

Orbits of three perturbing candidates are projected on the ecliptic plane. Note that Powell's object currently lies inside Neptune's orbit, just 23 astronomical units from the Sun. *Sky & Telescope* diagram.

THE SKY ALREADY SWEPT

The probable location of a 10th planet is constrained to some extent by the survey work of Tombaugh and others. In 14 years of searching before and after his discovery of Pluto, Tombaugh examined 45 million stars — nearly the entire sky visible from the Lowell Observatory. He is confident that no planet brighter than magnitude 16.5 exists within the 70 percent of the sky he covered. He could have detected a Neptune-size planet some 200 a.u. away. Moreover, Tombaugh concluded, "Other planets like Pluto do not appear to exist out to a distance of 60 astronomical units." Of course, Pluto-like planets may exist farther out, but their tiny perturbations, like Pluto's, would be immeasurably small.

In 1977, Charles T. Kowal began a new systematic search for undiscovered bodies in the solar system using the Palomar 48-inch Schmidt telescope. It has almost 14 times the light-gathering power of the 13-inch astrograph that Tombaugh used to find Pluto. Kowal's seven-year search covered 15° above and below the ecliptic. He found five comets and 15 asteroids, including Chiron, the most distant of all known asteroids, but not a 10th planet.

He is doubtful that any sizable planet lies within the 30° belt of his survey, but he wouldn't be surprised if a new planet with a high orbital inclination were discovered. Had Pluto been its farthest north or south of the ecliptic (17°.2), it would have been outside his field of search.

Kowal himself made an attempt to calculate the location of a 10th planet and came up with numbers similar to those of Harrington and Van Flandern: a planet several times the mass of Earth and bright enough that Tombaugh should have discovered it. "I spent many years of my life blinking photographic plates," says Kowal, "and I know how easy it is to miss something."

Of his calculations, Kowal notes, "I obtained perfectly reasonable predictions of the orbit of the unknown planet by first using the residuals of Uranus, and then those of Neptune. The only problem is, the two predictions do not agree with each other." He hopes to return to this work soon.

After seven years at the telescope and blink microscope, Kowal formed an indelible conclusion: this kind of search for very faint planets is not feasible. It is too time-consuming and exhausting.

PROBLEMS WITH THE DATA?

For a team of astrodynamicists at Caltech's Jet Propulsion Laboratory a decade ago, problems with the motion of Uranus and Neptune switched from theoretical curiosity to practical urgency. Their predictions would have extraordinary consequences. They had the responsibility to position Voyager 2 so that Saturn's gravity would redirect the craft toward Uranus' cloud tops, rings, and moons. Then they would use that planet for another gravity assist to yet-more-distant Neptune, arriving with such punctuality that Neptune could redirect the spacecraft's course toward its moon Triton. The dynamicists had to know with great accuracy how both Uranus and Neptune were moving and exactly where they would be when Voyager 2 flew past them.

E. Myles Standish, Jr., and his JPL colleagues recalculated the orbits of Uranus and Neptune. The ephemeris they created for Uranus very accurately predicted the position of the planet when Voyager 2 arrived. Their ephemeris for Neptune was equally successful when Voyager 2 got there last August. But they achieved these results only by ignoring all astrometric observations of Uranus and Neptune made prior to 1910.

Even though the new ephemeris was based on less than one revolution of

In 1978 James W. Christy (seated) discovered Pluto's satellite Charon on photographic plates taken with the U. S. Naval Observatory's 61-inch astrometric reflector in Flagstaff, Arizona. This find instantly settled the long controversy over Pluto's mass, and revitalized the search for yet another trans-Neptunian planet. Among those embarking on such a quest is Robert S. Harrington (standing), an expert in solar-system dynamics. U. S. Naval Observatory photograph.

Uranus, the planet was right where it was predicted to be. Standish therefore has no need for a 10th planet. He believes that known sources of systematic error in the 19th-century observations are more significant than many astronomers realize, easily as large as the alleged perturbations being used to predict Planet X. When the early observations are discarded, along with the handful of prediscovery sightings of Uranus and Neptune, and calculations are made on the remaining residuals, the need for a 10th planet falters. What discrepancies remain are small enough to be explained by observational error.

Standish has also detected differences in the way the early observations have been processed by the U. S. Naval Observatory, the Royal Greenwich Observatory, and the Paris Observatory. He would like to reconcile the pre-1910 observations with the modern orbits by going back to the raw data and carefully converting the positions to a common reference system.

There is no way to rule out absolutely the existence of a 10th planet, he notes. But neither is it essential that one exist in order to account for the motions of the planets. And new measuring techniques offer hope of great refinements in our knowledge of precise planetary orbits.

One such method involves the Very Large Array of radio telescopes in Socorro, New Mexico, which has been observing the planets at radio wavelengths since 1984. The VLA's 27 dish antennas, each 82 feet across, move along railroad tracks to separations as great as 23 miles. Arrayed in this way, the dishes can resolve the direction of radio signals from planets with an accuracy of 0.02 arc second, some 20 times better than standard positional measurements in optical wavelengths.

But planets are extended rather than point sources of radio signals, which makes their exact positions difficult to establish. Astronomers at JPL and at NASA's Goddard Space Flight Center are attempting to solve this problem with the help of the most distant cosmic objects of all, quasars. The positions of these radio sources can be nailed down to 0.001 arc second using arrays of very widely separated radio telescopes, and they are much too far away to show any proper motion. Thus quasars can define a truly unchanging coordinate system.

A spacecraft in orbit around a planet could then provide a point-source radio signal much better than the planet's, allowing the body's position to be fixed against the background of quasars. This technique promises planetary positions good to 0.004 arc second, 100 times better than present optical methods. We could know the location of Neptune to within 54 miles, for example, though the planet lies at a distance of 2.8 *billion* miles.

Thinking over his discovery of Pluto and his 14 years of planet searching, Clyde Tombaugh has offered "Ten Special Commandments for a Would-Be Planet Hunter." The final commandment decrees: "Thou shalt not engage in any dissipation, that thy years may be many, for thou shalt need them to finish the job."

For his book Planets Beyond *(Wiley, 1988), Mark Littmann received the 1989 Science-Writing Award of the American Institute of Physics. He especially thanks E. Myles Standish, Jr., for a helpful critique of this article.*

The hunt for Planet X

Is the gravity of an unseen tenth planet pulling Uranus and Neptune off course? Some astronomers think that the answer is yes. But others disagree

Ken Croswell

ASTRONOMERS are looking for an unseen world that they call Planet X. If it exists, it orbits billions of kilometres from the Sun, far beyond the orbits of Uranus, Neptune and Pluto. As it creeps through the frigid outer reaches of the Solar System, Planet X's gravity perturbs the orbits of Uranus and Neptune. And the planet is so far away that sunlight falling on it has barely 0·01 per cent the strength it has on Earth, making the planet colder than any known object in the Solar System.

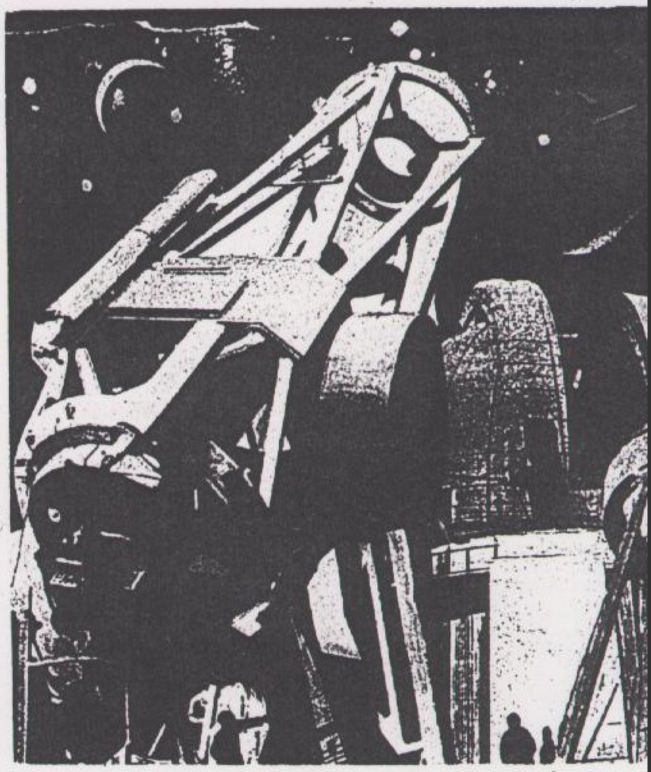
Some astronomers are so sure that Planet X exists that they are searching for it, armed with telescopes, photographic plates, and a machine specifically designed to find unseen planets. By analysing subtle deviations in the motions of Uranus and Neptune from that predicted, these scientists hope to locate Planet X.

Other astronomers think that the search for Planet X is futile. They say that the problems with Uranus and Neptune arise not from Planet X but from observational errors committed during the 19th century. Astronomers must rely on old data to calculate the planets' orbits because Uranus and Neptune take so long to circle the Sun. If the old data are bad, so are the calculated orbits; and if the calculated orbits are bad, then Uranus and Neptune will deviate from them, even without Planet X.

People have wondered whether there are more planets in the outer Solar System ever since the English astronomer William Herschel discovered Uranus in 1781. Herschel found Uranus quite by accident. While he was looking for double stars, he noticed an object in the constellation Gemini that did not look like a star. Herschel thought he had discovered a comet. Instead, the strange body turned out to be a planet twice as distant as Saturn.

After Herschel's discovery, astronomers computed Uranus's orbit. The planet had been observed as early as 1690 by astronomers who mistook it for a star. These old observations helped scientists calculate what should have been a good orbit, because this requires observations spanning a complete revolution. But, over the years, Uranus refused to follow the course the orbit predicted. The planet deviated from the predicted orbit by up to 100 arcseconds (1 arcsecond is 1/3600 of a degree).

In the 1840s, the English astronomer John Couch Adams and the French astronomer Urbain Leverrier speculated independently that a massive planet orbited the Sun beyond Uranus. Its gravity pulled Uranus from the course it would otherwise follow. Adams and Leverrier analysed the motion of Uranus and were able to predict the position of the unknown planet. In 1846, the German astronomers Johann Galle and Heinrich d'Arrest discovered Neptune, precisely where Adams and Leverrier said the planet would be. Neptune is more than a billion kilometres farther away from the Sun than Uranus. Because it has 17 times the mass of Earth, Neptune's gravity can easily pull Uranus off course.



The discovery of Neptune inspired other astronomers to search for unknown planets by looking for small perturbations of the known planets. In the early 1900s, American astronomer Percival Lowell looked closely at the orbit of Uranus, which he thought was still not quite right. He predicted that a ninth planet was perturbing it and estimated that the mass of this unseen planet was 6·7 times that of the Earth.

For many years, Lowell used his observatory in Flagstaff, Arizona, to search for this world, which he called "Planet X". Lowell died in 1916 without having found his Planet X. But in 1929, Lowell Observatory resumed the search, and in 1930 Clyde Tombaugh discovered Pluto, not far from where Lowell had thought it might be.

But Pluto is not Lowell's Planet X; it is far too small to perturb the other planets. Pluto is only 1/500th of the mass of Earth, nowhere near the 6·7 times the mass of the Earth Lowell had assigned to his Planet X. And not only is Pluto far smaller than any other planet, but it is also smaller than several moons, including our own. In fact, Pluto is so tiny that some astronomers do not consider it a genuine planet.

In order to know whether a planet is following the course it should, astronomers must calculate the planet's orbit accurately, taking into account the gravitational influences of all other planets. But computing the orbits of Uranus and Neptune is not easy, because an accurate orbit requires observations that span at least a full orbital period. For planets such as Mars and Jupiter, which circle the Sun in just a few years, this is no problem. But Uranus takes 84 years to circle the Sun, Neptune 165 years. This means that Uranus has circled the Sun only two-and-a-half times since its discovery in 1781, and Neptune has yet to complete a full orbit since its discovery in 1846. (We cannot use Pluto to test for the existence of Planet X, because no one knows Pluto's orbit accurately enough; it takes 248 years to circle the Sun and so has completed only a quarter of its orbit since its discovery in 1930.)

In principle, Uranus's orbit should be well determined. It was observed as early as 1690, so we have data on the planet over more than three and a half revolutions. But there are problems. No single orbit seems to fit all the data. Kenneth Seidelmann of the US Naval Observatory, in Washington DC, can calculate Uranus's orbit only by ignoring the data before 1900. Seidelmann can fit the Uranus data during the most recent orbit, but not during previous ones.

This same problem occurred during the early 1800s, before Neptune was discovered. Astronomers at that time could not reconcile all the Uranus data with a single orbit, so they threw out the oldest data in order to compute the planet's path. The reason for the trouble then was that Neptune was pulling Uranus off course.

Illustrations by Ken Cox

Galileo recorded Neptune

Neptune, once the source of Uranus's difficulties, is now having problems itself. Theorists can make the data accumulated since the planet's discovery fit a single orbit. But about ten years after scientists compute an orbit, Neptune begins to deviate from it. Because Neptune has not yet completed an orbit since its discovery in 1846, the problem may simply be that we have not yet determined its orbit accurately. But Neptune has completed 88 per cent of an orbit, and Seidelmann considers it surprising that, with so much data, Neptune still runs off course.

Prior to Neptune's discovery, two astronomers observed the planet without realising it. The positions they recorded for Neptune give us vital data on the planet over more than a full orbit and, therefore, may bolster the case for Planet X.

Galileo Galilei observed Neptune in late 1612 and early 1613, nearly two-and-a-half centuries before the planet's discovery. At the time, Galileo was studying the four large moons of Jupiter. In 1979 Steven Albers calculated that Neptune had passed close to Jupiter in 1613, three years after Galileo had discovered the moons. Albers's calculation inspired Charles Kowal of the Space Telescope Science Institute and Stillman Drake of the University of Toronto to search through Galileo's notebooks. They found that Galileo had indeed recorded a star where no star exists today. This so called "star" must have been Neptune.

Galileo's position for Neptune is quite far from the one Neptune should have had according to recent calculations of its orbit. Unfortunately, Galileo probably did not record the planet's position accurately, for he was much more interested in Jupiter and its moons. To him, Neptune was just another star. Few scientists consider Galileo's observations of any help in determining whether Planet X exists.

Of far greater value are two observations that French astronomer Joseph Lalande made in 1795. Lalande was compiling a huge star catalogue and measured accurately the positions of thousands of stars. On 8 May 1795, and again on 10 May 1795, Lalande recorded Neptune.

The positions Lalande measured for Neptune on the two different nights agree with each other, but they differ greatly from where Neptune should have been according to current calculations. Typically, Lalande measured the positions of stars to an accuracy of 2 or 3 arcseconds, yet his observation of Neptune on 8 May is off the predicted position by 12 arcseconds and his observation of 10 May is off by 13 arcseconds.

It is possible that Lalande made a mistake in his calculations, and that he made the same mistake twice. But if his observations are correct, they lend support to the existence of Planet X, which must have been pulling Neptune significantly from its proper course.

Today, Uranus and Neptune are no longer the only objects that scientists can study to detect the influence of Planet X. Four spacecraft, all launched in the 1970s, have now reached the outer Solar System. The first to be launched were Pioneer 10 and Pioneer 11. But these spacecraft provide evidence against Planet X. According to John Anderson of the Jet Propulsion Laboratory in Pasadena, California, the probes are exactly on course. Pioneer 10 flew past Jupiter in 1973, and Pioneer 11 flew past Jupiter in 1974 and Saturn in 1979. The two ships are now heading out of the Solar System in opposite directions, and the steady course of each means there can be no large planet near either.

In the 1970s, the US launched Voyager 1 and Voyager 2.

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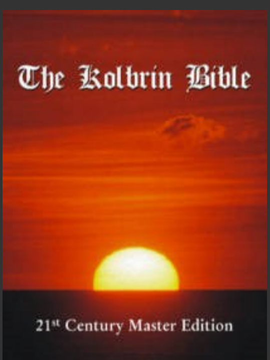

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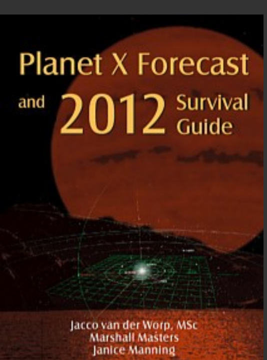

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Voyager 1 flew past Jupiter in 1979 and Saturn in 1980; Voyager 2 flew past Jupiter in 1979, Saturn in 1981, Uranus in 1986 and Neptune in 1989. Unfortunately, both spacecraft are travelling in the same direction as Pioneer 11, so they probably will not provide any additional information on Planet X.

Because the Pioneer spacecraft are travelling unperturbed, the case for Planet X rests entirely on the deviations in the motions of Uranus and Neptune. Are they real or do they result from observational error? The deviations are tiny. Except for Lalande's observations of Neptune in 1795, the deviations in the motions of Uranus and Neptune are less than 1 arcsecond. In comparison, the deviations in the orbit of Uranus before Neptune was discovered were as high as 100 arcseconds.

Scientists interpret the deviations in different ways. Despite the small size of the deviations, Seidelmann believes that they are probably real and do not result from observational error. In his view, Planet X is a good explanation for the problems with Uranus and Neptune.

On the other hand, E. Myles Standish, Jr., of the Jet Propulsion Laboratory in Pasadena, California, thinks the deviations are the result of error. In particular, Standish says that the data before 1910 are faulty. It was only in 1910 that astronomers began to use micrometers to measure the positions of Uranus and Neptune. A micrometer is a device that gives a more accurate measure of a planet's position.

Is the law of gravity incorrect?

Standish believes that there is no evidence for Planet X. He says that in the case of Uranus, if one considers only the data since 1910—which span a complete revolution—there is no problem with the planet's motion. In the case of Neptune, the observations since 1910 cover only half a revolution. Therefore, it is impossible to compute an accurate orbit for the planet. Standish believes this is why Neptune runs away from its predicted course: simply because its orbit is not well determined. Furthermore, because the orbit is not well-known, we do not really know where Neptune should have been in 1795, when Lalande observed the planet. Lalande's observations of Neptune differ from the prediction not because he was wrong but because the prediction is.

If the deviations are real, however, Planet X is quite the best explanation for them, though not the only one. The problem could be that our knowledge of the law of gravity is not quite correct. Few astronomers are willing to consider such an extreme possibility, but we have been wrong before. At the turn of the century, the planet Mercury was off course. Astronomers thought a planet named Vulcan circled even closer to the Sun and pulled Mercury off its predicted path. Some astronomers even claimed to have seen Vulcan.

But Vulcan does not exist. The problem with Mercury was that astronomers did not then know about Einstein's general theory of relativity, a modification of Newton's law of gravity. Today, it is possible, albeit unlikely, that Uranus and Neptune are off course simply because the law of gravity we use in computing their orbits is slightly defective.

No one can rule out problems with the data. But the deviations in the motions of Uranus and Neptune, if real, strongly hint that there is a massive planet in the outer Solar System. The only way to know for sure, of course, is to find Planet X.

The first search for a planet beyond Pluto began in 1930. After he found Pluto, Tombaugh continued to hunt for distant planets, starting, in fact, with the photographic plate on which he had discovered Pluto. Tombaugh searched for far-off planets until 1943, scrutinising most of the sky that is visible from Lowell Observatory in Arizona. He found asteroids, star clusters, galaxies, and a comet, but no new planets.

From 1976 to 1985, Charles Kowal conducted another search, examining the sky for comets, asteroids, and Planet X. Kowal covered less sky than Tombaugh but looked at much fainter objects. In November 1977, Kowal discovered Chiron, an asteroid-turned-comet, between the orbits of Saturn and Uranus ("The changing face of Chiron", *New Scientist*, 25 August). But with a diameter of only 200 kilometres, Chiron was certainly no Planet X.

More recently, Robert Harrington of the US Naval Observatory has led the search. Although he admits that the deviations in the motions of Uranus and Neptune could be due to observational error, Harrington has nonetheless used those deviations in an attempt to locate Planet X. He believes this planet has a mass between three and five times that of the Earth, making Planet X bigger than Earth but smaller than Uranus and Neptune.

The planet Harrington expects to find is a distant one, with an average distance of 15 billion kilometres from the Sun. By comparison, the average distances of Neptune and Pluto are 4·5 billion kilometres and 5·9 billion kilometres respectively. Harrington's Planet X is so far from the Sun that it takes a thousand years to make a single orbit.

The distance of Planet X varies considerably, because its orbit is quite elongated. At its closest, Planet X comes within 9 billion kilometres of the Sun; at its farthest, it recedes to 21 billion kilometres. According to Harrington, Planet X reached its closest point in the late 1700s and is now heading away from us. Harrington's calculations also indicate the planet has an orbit which is inclined at about 30 degrees to the plane of the Solar System. Harrington believes his planet lies in the southern sky. His best guess is that Planet X is in the constellation Centaurus, which is near the Southern Cross.

At Black Birch observatory in New Zealand, Robert Hindsley is exposing photographic plates of the area in and around Centaurus. He then ships the plates to Washington, where Harrington examines them on an instrument called a blink comparator. This machine holds two plates of the same region of the sky taken on two different nights and alternates the view of them. Stars, which are fixed, remain steady as the plates alternate, but a planet, which moves slightly from night to night, would jump back and forth from one plate to the

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other. Tombaugh used a blink comparator to find Pluto in 1930, and Kowal used one to find Chiron in 1977.

Although Harrington acknowledges that the deviations in Uranus and Neptune could be spurious, he is not worried about the negative results from the Pioneer spacecraft. Neither Pioneer 10 nor Pioneer 11 travelled near Harrington's Planet X, so neither should feel its gravitational pull. In fact, Harrington predicted negative results from the Pioneer data, even before it was analysed. Harrington does take Tombaugh's extensive search seriously, however. According to his calculations, Planet X was too far south in 1930 for Tombaugh to have spotted it from Arizona.

In addition to causing the deviations in the motions of Uranus and Neptune, Planet X may explain the odd orbits of Neptune's satellites and also of Pluto. Triton and Nereid, two of Neptune's moons, have strange orbits. Though it is a large moon, Triton circles Neptune backward in a decaying orbit. Nereid orbits Neptune in the correct direction but follows an extremely elongated path.

Pluto also has a strange orbit. Its distance from the Sun varies so much that at times—for instance, today—Pluto lies closer to the Sun than Neptune does. At other times, Pluto is billions of kilometres farther from the Sun than Neptune. Furthermore, Pluto's orbit is inclined at 17 degrees to the plane of the Solar System.

Harrington believes that long ago, his Planet X may have collided with Neptune. At that time, Triton, Nereid, and Pluto were all satellites revolving around Neptune in normal, circular orbits. Planet X reversed Triton's orbit, stretched out Nereid's orbit, and kicked Pluto away from Neptune.

In the late 1970s, Harrington and Thomas van Flandern carried out computer simulations to see what characteristics an intruder planet might need in order to account for the present orbits of Triton, Nereid, and Pluto. Harrington and van Flandern found that the planet would have to be a few times the mass of the Earth and have an elongated orbit—in other words, it would be a lot like Harrington's Planet X.

Did planet X collide with Neptune?

Since 1988, when Harrington published his prediction for Planet X's location, two other predictions have appeared. These predicted planets differ both from Harrington's and from each other. Conley Powell of Teledyne-Brown Engineering in Huntsville, Alabama, has analysed the motion of Uranus. He believes Planet X is in the constellation of Virgo. Powell's planet is smaller and closer than Harrington's. He puts its mass at less than the Earth's and gives it a distance similar to Pluto's. Meanwhile, Brazilian astronomers Rodney Gomes and Sylvio Ferraz-Mello believe a more distant planet may lie in the constellations of Cancer or Gemini.

The two predicted planets lie farther north than Harrington's. So if they exist, Tombaugh should have found them. In fact, all three planets—including Harrington's—are brighter than Pluto was at the time of its discovery. This convinces some astronomers that none of these worlds really exist. If they did, they would have been found long ago. Furthermore, Standish points out that the three different predictions differ greatly from one another, even though they arise from the same data. That, says Standish, is proof that the data—even if correct—cannot be used to locate Planet X.

Nevertheless, the search will continue. Until Uranus and Neptune behave themselves, Seidelmann sees no reason to give up on Planet X. And Harrington has vowed to continue the search as long as he can come up with some idea as to where the planet is. □

Ken Croswell received his doctorate in astronomy from Harvard University and has written for *Astronomy, Astronomy Now*, and Time-Life Books.

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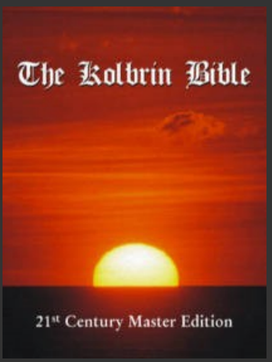

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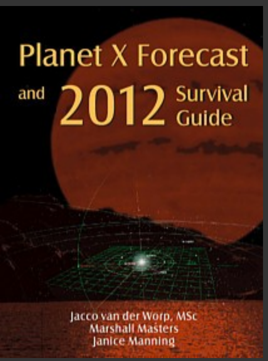

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PLANET X / NEMESIS

result of a quest initiated because of observed irregularities in the orbits of Uranus and Neptune. Astronomers had believed for some time that the gravitational influence of an undetected planet was responsible for the perturbations, and with Tombaugh's find, the culprit seemed to have been apprehended. But by the late 1970s, improved estimates of Pluto's mass had revealed that it was far too small to disturb its giant neighbors, and scientists began to suspect that lurking somewhere beyond the ninth planet was a tenth—known, appropriately, as Planet X. A new generation of planet hunters took up the challenge. "I wish 'em luck," said octogenarian Tombaugh in 1988. "They're in for a lot of hard work."

Two of the leading workers are Robert Harrington and Kenneth Seidelmann, both of the U.S. Naval Observatory in Washington, D.C. Much of their energy has gone into figuring out just where to look, with computers playing a major role. Seidelmann's main contribution is to determine as accurately as possible the differences between the predicted and actual locations of Uranus and Neptune, known as residuals. He does so by comparing the latest sightings of the two planets with a computer simulation of their orbits based on observational data up to 1978. The measured discrepancies become the basis for more laborious rounds of modeling overseen by Harrington. Employing a program that simulates a ten-planet Solar System, Harrington plugs in different values for the mass, distance, and orbit of the unknown Planet X to see which will produce the observed effects on Uranus and Neptune. By the end of the 1980s, the computer had run through more than a third of a million simulations and come up with fewer than 200 possibilities.

The numbers seem to indicate that Planet X should currently be somewhere in a small patch of the southern sky near the constellation Centaurus, but searches of the area have so far turned up nothing. Some astronomers doubt they ever will. "Most of it's a bunch of nonsense," says Brian Marsden of the Harvard-Smithsonian Center for Astrophysics. "It is more likely that the residuals have some other explanation in some kind of observational error or instrumental error or systematic error. I think those have to be considered first before we jump to wild conclusions about distant planets." However, until any such errors can be brought to light, Planet X will remain a plausible albeit elusive quarry.

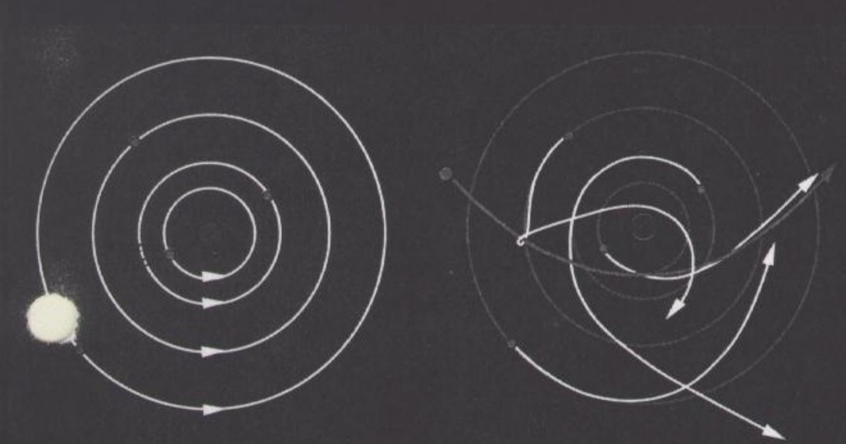
NEMESIS

A few theorists think there may even be another member of the Solar System, far beyond Planet X—and that it may be a killer. Fossil records show that about 65 million years ago, more than two-thirds of the species living on Earth, including all the dinosaurs, simply disappeared. In 1979, the late physicist Luis Alvarez and his son Walter, a geologist, proposed that the disaster occurred when a small asteroid or comet hit Earth, throwing a thick pall of dust into the upper atmosphere and cutting off sunlight for several years; most plants would have died within months, disrupting the food chain and leading to the mass extinctions. Although the theory created a storm of

The Case for Planet X

For more than half a century—and with varying degrees of intensity—some astronomers have proposed the existence of a tenth planet. Known as Planet X, the unseen world is invoked to explain certain anomalies in the behavior of Uranus, whose calculated orbit works for one circuit but not the next, and Neptune, whose predicted positions are noticeably in error after several years. Planet X, if it exists, might also explain the odd orbital dynamics of Neptune's moons Triton and Nereid, and the unexpected size and makeup of Pluto, which is so much smaller and rockier than its huge, gaseous neighbors.

The hunt for Planet X—based on calculations of its presumed mass and orbit—requires painstaking searches of designated patches of sky. In 1846 and again in 1930, such efforts paid off in the discoveries of Neptune and Pluto. Similar dedication may one day turn up a body that so far lives only in theory.



The fourth moon. One scenario to account for the dynamics of the outer Solar System hypothesizes that Neptune once had four satellites—until Planet X *(red)* plowed through the system. The gravitational effects of its passage sent Triton into a backward circuit around Neptune, stretched Nereid's orbit out to six million miles, and knocked Pluto into an inclined and elliptical path around the Sun. Neptune's erstwhile fourth moon was captured by the intruder.

The first step. To find Planet X, scientists must first calculate its presumed mass and orbit. In the Solar System shown here, Planet X has a mass between two and five times that of Earth and travels in an orbit even more inclined and elliptical than Pluto's. At the farthest point in its orbit, Planet X would be 100 astronomical units from the Sun (or 100 times the distance from the Sun to Earth) and would take from 350 to 1,000 years to complete one circuit.

controversy when first introduced, it now seems well established—the most convincing evidence being that sedimentary layers from that epoch contain an unusual abundance of iridium, a metal that is otherwise rare on Earth—but is relatively common in meteorites.

But what caused the asteroid impact in the first place? Was it just a random event in the violent history of the Solar System, or was it part of a pattern? Through more recent, and more detailed, statistical analysis of the fossil record, geologists have found that mass extinctions seem to be periodic, occurring about every 26 million years. Such periodicity, concluded some, could only be related to the passage of a massive object in a far-flung, extremely elliptical orbit around the Sun. Its gravitational pull, according to this theory, would regularly unleash a hail of potentially lethal comets and asteroids from the Oort cloud, a collection of frozen chunks of matter that astronomers believe encapsulates the Solar System.

The hypothetical body—known as Nemesis, or the Death Star—has drawn an even larger group of detractors than Planet X. For one thing, though predicted to be of stellar proportions, it would have to be very dim and cold to have escaped detection by both optical and infrared telescopes. And periodic extinctions have at least one other possible explanation: The entire Solar System is thought to oscillate up and down within the Milky Way, passing every 30 million years or so through the galactic plane, where clouds of interstellar dust and gas could send Oort cloud comets flying, or higher levels of cosmic radiation could directly affect Earth's climate. Even those who think Nemesis exists admit that they have no other evidence beyond the extinction pattern, since Nemesis would currently be too far away to have any measurable effect on planetary behavior. So while Harrington and other Planet X hunters have been able to improve their chances with new data about the orbits of the outer planets, Nemesis advocates can do nothing to narrow their search. The reasons for looking are too few and the places to look too numerous for Nemesis to have stirred much serious interest among members of the astronomical community.

INVISIBLE COMPANIONS

Despite the lack of hard evidence, Nemesis supporters are somewhat encouraged by the fact that companionless stars such as the Sun are relatively rare in the galaxy. About 80 percent of the stars visible in the Milky Way appear to be part of double, triple, or even quadruple star systems—most likely a consequence of the manner in which stars are born. Under certain conditions, such as the passage of a shock wave from a nearby supernova explosion, vast clouds of gas and dust in the spiral arms of galaxies may collapse inward upon themselves, creating regions of high density, pressure, and temperature. As the contraction proceeds, the cloud, or nebula, begins to fragment, and these dense regions form protostars—concentrations of mass whose gravity continues to pull in more dust and gas from the nebula's remnants. Eventually, pressure and temperature become high enough within these protostars to generate fusion reactions, and the newborn stars begin to shine. But before the nuclear furnaces get going, protostars themselves may fragment, the separate pieces typically evolving into stars that are almost certain to be locked in an orbital relationship throughout their history.

Of course, if the Sun does have a companion, it cannot be an identical twin or even an undersize sibling, whose light would be easily detected. One intriguing possibility is that Nemesis could be a strange and still-controversial celestial character known as a brown dwarf, an object that falls somewhere between planet and star. According to standard theories, planets form in a way that is different from the evolution of stars, accreting from small clumps of leftover dust and gas in a disk surrounding a protostar or newborn star. Their initial buildup results mostly from collisions with other bits and pieces in the disk, not through a collapse process or because of conditions of heightened pressure and temperature. Consequently, although they can grow quite large, they can never accumulate enough mass to initiate fusion reactions and become stars. But the theories also allow for another scenario: Some protostars, or perhaps protostar fragments, may never gather sufficient mass to ignite. Such a body would begin its life as a star does, yet, like a planet, would emit little energy of its own. It would be, by its popular moniker, a brown dwarf.

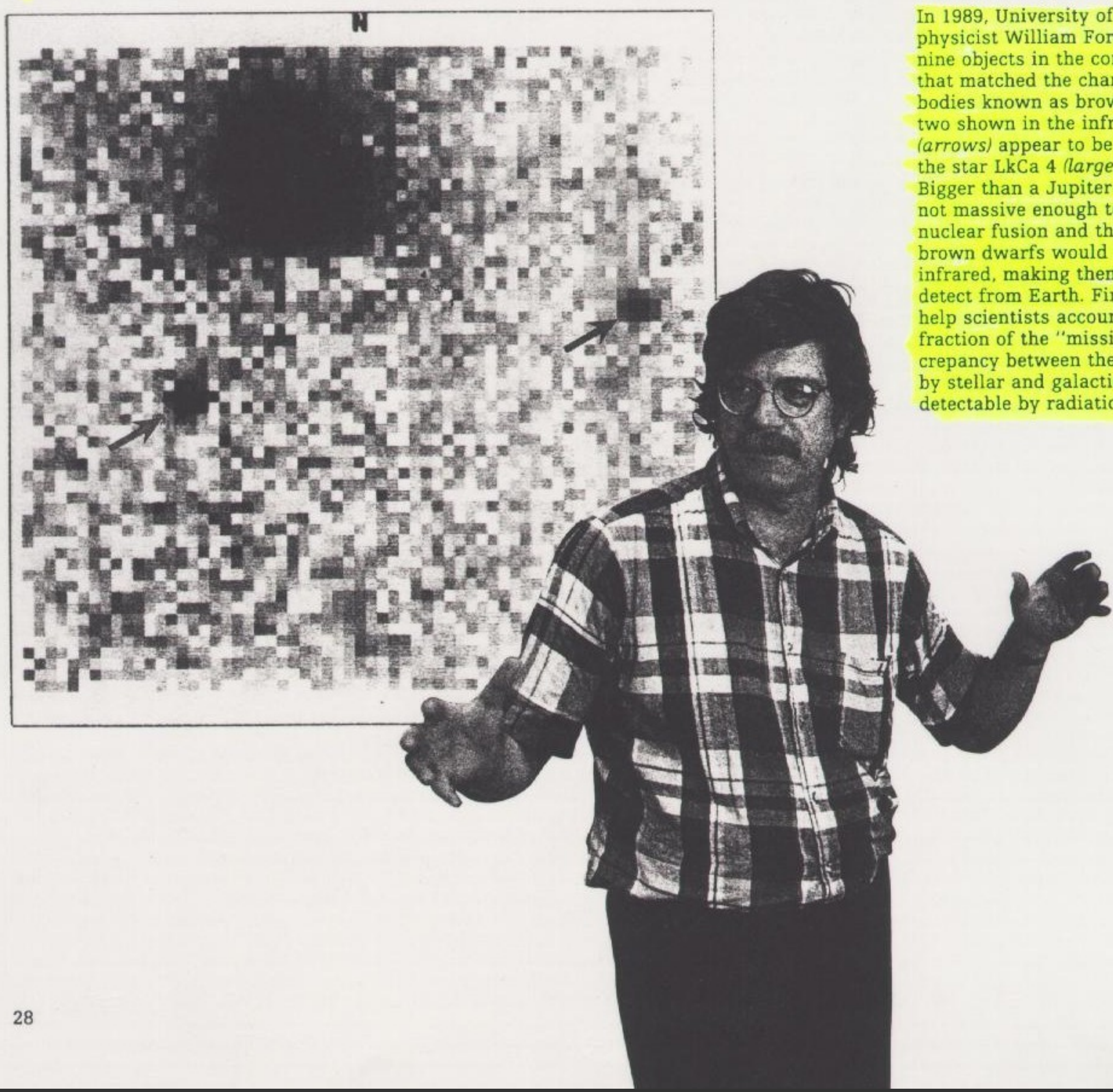
Brown dwarfs, if they exist, would satisfy theorists in at least two regards. For starters, they would fill a gap in the observed sequence of sizes of celestial objects. The largest known planet, Jupiter, has just one-tenth of one percent of the mass of the Sun, a medium-size star. Calculations indicate that the smallest stars require at least eight percent of a solar mass, or eighty Jupiters, to sustain fusion, and that planets could feasibly be as much as ten times larger than Jupiter. Brown dwarfs would cover the ground in between. They

80% OF THE STARS IN OUR GALAXY ARE BINARY! GJ

The missing mate. Another hypothetical body, put forward to explain recurring mass extinctions on Earth, is known as Nemesis. This dark stellar companion to the Sun is theorized to be no more than .08 solar masses, with an orbit *(red)* that takes it out to 170,000 astronomical units, or about three-fifths the distance to the nearest known stars. But roughly every 26 million years, Nemesis returns to the Sun's neighborhood, passing en route through the Oort cloud—a huge sphere of cometary material, left over from the birth of the Solar System—and sending a rain of comets *(arrow)* toward the inner planets. The resulting meteoritic bombardment might have had catastrophic effects on Earth's climate and life forms.

might also help solve the enduring cosmological riddle of the universe's missing mass. Measurements of the gravitational forces at work within galaxies suggest that they should contain as much as ten times more matter than can be accounted for by observation. Proposers of brown dwarfs have reason to believe they should be common in the universe. A census of the skies reveals that very bright, very massive stars are relatively rare, but as mass and luminosity decline, the population increases. By extension, bodies with the postulated characteristics of brown dwarfs ought to be as common as grains of sand on a beach. The total bulk of so many brown dwarfs might be enough to account for the missing mass.

Most scientists doubt the existence of a brown dwarf as a companion to the Sun, but several teams of investigators are hunting for them in the vicinity of other stars. Because brown dwarfs give off little or no visible light, the searchers have had to come up with ingenious methods for detecting their presence. A dark body orbiting a visible star ought to betray itself by creating



In 1989, University of Rochester astrophysicist William Forrest *(below)* found nine objects in the constellation Taurus that matched the characteristics of bodies known as brown dwarfs. The two shown in the infrared image at left *(arrows)* appear to be associated with the star LkCa 4 *(large shape at top)*. Bigger than a Jupiter-size planet, but not massive enough to have triggered nuclear fusion and thus become a star, brown dwarfs would radiate in the infrared, making them very difficult to detect from Earth. Finding them could help scientists account for a significant fraction of the "missing mass"—the discrepancy between the mass indicated by stellar and galactic motions and the detectable by radiation.

a slight wobble in the motion of its bright companion, which would be revealed by a periodic shift in the star's spectrum. A group of Canadian astronomers looking for such spectral shifts with equipment designed to detect extremely minute variations announced in 1987 that they had found evidence for the existence of "low-mass companions" to at least two nearby stars and perhaps as many as seven. Bruce Campbell, speaking for the team, cautioned that they had determined nothing more than the probable masses of the unseen objects, which were between one and ten times that of Jupiter. The news, while exciting for its suggestion that planetary systems may be quite common, was discouraging for brown dwarf aficionados: Bodies of such mass were too small, and objects on the scale of brown dwarfs, which would create larger spectral shifts, ought to have been easier to spot. Having failed to detect any bodies in the required size range, Campbell was ready to rule out brown dwarfs entirely.

HOPEFUL SIGNS

Others questioned such a categorical conclusion. Eliminating an entire class of objects on the basis of a single set of observations seemed premature to some astronomers, and within months of the Canadians' announcement, two observers from the University of Hawaii reported that they had discovered something with at least one of the characteristics of a brown dwarf. Searching for infrared emissions—that is, levels of heat too weak to cause visible radiation—from bodies orbiting small stars, Benjamin Zuckerman and Eric Becklin found a clear-cut signal near the star Giclas 29-38. "It sticks out like a sore thumb," said Zuckerman. The object's temperature closely matched predictions for the thermal output of a brown dwarf, but Zuckerman remained cautious. "We don't know that we've seen a brown dwarf," he noted. "I hope we have. But no matter what it is, we've definitely seen something interesting that we have to understand."

Observations made by several other groups of astronomers in 1988 and 1989 seemed to hint at still more brown dwarfs, but there was enough ambiguity in the data to enable skeptics to pick holes in the claims. Many of the candidates, for example, fell very close to the borderline between brown dwarf and star in terms of their temperature. Although the objects under scrutiny were apparently too cool to be stars, only a minor adjustment to the theoretical minimum stellar temperature would suffice for them to be classified as low-mass stars. Many astronomers felt safer broadening the definition of a known type of object than admitting the possibility of an entirely new sort of celestial entity.

The strongest evidence in support of brown dwarfs was reported in the summer of 1989 by a group led by William J. Forrest of the University of Rochester. In an approach similar to Zuckerman and Becklin's, Forrest's team set out to detect brown dwarfs by their heat; the difference was that they would look for ones thought to be at their hottest. During the first million years of its existence, a body destined to become a brown dwarf should

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STARS

THE VATICAN WENT THROUGH A LOT OF 'RED-TAPE' TO GET THIS TELESCOPE BUILT! WHY? - GJ

HE MADE THE STARS ALSO:
The Vatican's astronomers combine cosmology and theology

By Victor Dricks

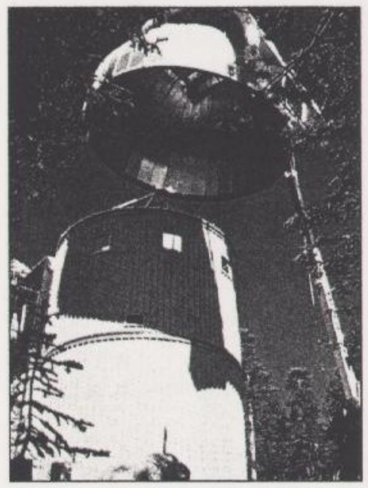
Atop a 10,436-foot peak on Mount Graham in southeastern Arizona, red squirrels, officially an endangered species, scamper across a clearing the San Carlos Apache tribe considers sacred. Surrounded by dense vegetation, the Vatican's new $3 million telescope stands like a monument to man's timeless fascination with the heavens. Like the Native Americans before them, a handful of Jesuit priests have come to Mount Graham to ponder the mysteries of creation.

The Vatican's new Advanced Technology Telescope on Mount Graham in Arizona will allow the Church's astronomers to peer even further into the mysteries of the universe.

The Vatican doesn't acknowledge the Apaches' claim to a unique usage of the mountain. "But we're very aware of the historical and ecological significance of this site," says the Reverend Chris Corbally, one of six Vatican astronomers using the telescope. "Our observatory is built on land occupied by an endangered species, and our mission is a demonstration of the possibility of peaceful coexistence between religion, nature, and science."

For more than four hundred years, astronomers at the Vatican have scanned the heavens from Rome. The work of early Jesuit astronomers provided Pope Gregory XIII with the data he needed to replace the Julian calendar with the Gregorian. But glare from city lights has rendered stargazing increasingly difficult in Rome. Since 1981, the Vatican Observatory has relied on its Tucson research base to keep abreast of cosmological developments that could have theological implications, including theories about the creation, evolution, and fate of the universe—topics that Pope John Paul II has taken a keen interest in. "Our job is to serve as scientific advisers to the pope and help the Vatican maintain an open dialogue with

"FATE OF THE UNIVERSE" RETURN OF PLANET X ? GJ.



the scientific community," says Martin McCarthy, a Jesuit astronomer for 36 years.

To do this, generous donors have furnished the Vatican's astronomers with a remarkable new instrument. At 1.8 meters in diameter, the main mirror of the Vatican's Advanced Technology Telescope, constructed by the University of Arizona, is of moderate size but boasts the most exact surface of any mirror ever cast for ground-based astronomy. Capable of providing extremely sharp, detailed images of celestial objects, the new telescope also allows the Vatican astronomers to make observations at regular intervals over a long period of time, usually a difficult task because astronomers gain access to premier instruments for only a week or two each year.

The astronomers have already put their new telescope to good use. Corbally, for example, is studying a small group of stars that appear to be old, although they reside in a part of the sky where young stars abound. The Vatican Observatory director, the Reverend George Coyne, uses the telescope to peek into star-forming regions in the constellation of Cassiopeia. The Reverend Richard Boyle is working with colleagues in Lithuania and Rome to study a population of stars in our own Milky Way galaxy, using a technique called photometry, which measures the intensity of light. In addition, the Vatican permits outside astronomers to use the observatory.

"The Vatican astronomers do first-rate work," says Arizona State University astronomer Peter Wehinger. "They are very fortunate because they are supported by a well-funded organization that appreciates the quest for astronomical knowledge."

Vatican astronomers bring to their work formal religious training coupled with advanced degrees in astronomy, and by all accounts, they've earned considerable respect from their peers. In fact, Corbally jokes, the Jesuits spend so much time peering through their telescope and attending scientific conferences that they find it easier to communicate with other astronomers than with their brothers in Rome, who complain that their reports can be hard to understand. They operate, Corbally says, in the same tradition as the German astronomer Johannes Kepler, who had strong mystical leanings, and Sir Isaac Newton, who viewed science as a means of interpreting God's handiwork.

"Always, the great minds in science have had this spiritual dimension," Corbally says. "And this is something the Church encourages." Once a symbol of dogmatic opposition to scientific ideas that clashed with theology, in recent years the Church has sponsored world-class conferences on topics long considered taboo, such as cosmology and human evolution, indicating that the Church has itself evolved over the years. ∞

A Faint and Lonely Brown Dwarf in the Solar Vicinity

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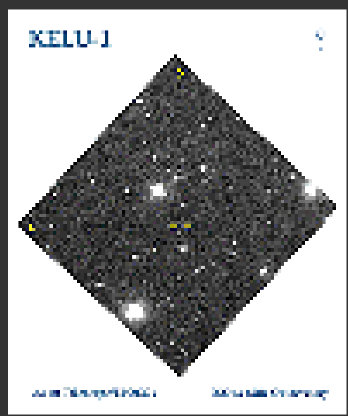

Discovery of KELU-1 Promises New Insights into Strange Objects

Brown Dwarfs are star-like objects which are too small to become real stars, yet too large to be real planets. Their mass is too small to ignite those nuclear processes which are responsible for the large energies and high temperatures of stars, but it is much larger than that of the planets we know in our solar system.

Until now, very few Brown Dwarfs have been securely identified as such. Two are members of double-star systems, and a few more are located deep within the Pleiades star cluster. Now, however, Maria Teresa Ruiz of the Astronomy Department at Universidad de Chile (Santiago de Chile), using telescopes at the ESO La Silla observatory, has just discovered one that is all alone and apparently quite near to us.

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Discovery of KELU-1 Promises New Insights into Strange Objects — Continued...

Contrary to the others which are influenced by other objects in their immediate surroundings, this new Brown Dwarf is unaffected and will thus be a perfect object for further investigations that may finally allow us to better understand these very interesting celestial bodies.

It has been suggested that Brown Dwarfs may constitute a substantial part of the unseen dark matter in our Galaxy. This discovery may therefore also have important implications for this highly relevant research area.

Searching for nearby faint stars

The story of this discovery goes back to 1987 when Maria Teresa Ruiz decided to embark upon a long-term search (known as the Calan-ESO proper-motion survey) for another type of unusual object, the so-called White Dwarfs, i.e. highly evolved, small and rather faint stars.

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Searching for nearby faint stars — Continued...

Although they have masses similar to that of the Sun, such stars are no larger than the Earth and are therefore extremely compact. They are particularly interesting, because they most probably represent the future end point of evolution of our Sun, some billions of years from now.

For this project, the Chilean astronomer obtained large-field photographic exposures with the 1-m ESO Schmidt telescope at La Silla, each covering a sky area of 5o.5 x 5o.5. When comparing plates of the same sky field obtained at time intervals of several years [1], she was able to detect, among the hundreds of thousands of stellar images on the plates, a few faint ones whose positions had changed a little in the meantime. The search technique is based on the fact that such a shift is a good indicator of the object being relatively nearby. It must therefore also be intrinsically faint, i.e. a potential White Dwarf candidate.

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Searching for nearby faint stars — Continued...

On every pair of plates, approximately twenty faint moving objects were detected with proper motions [2] of more than 0.25 arcsec per year. Indeed, follow-up spectroscopic observations showed that about 20 percent of these or about four per plate were White Dwarfs. Until now, a total of forty new White Dwarfs have been discovered during this very successful project, i.e. over ten times more than originally expected.

And then - a Brown Dwarf!

When checking two plates with a time inverval of 11 years, Maria Teresa Ruiz earlier this year discovered a very faint object in the southern constellation of Hydra (The Water-Snake), moving at 0.35 arcsec per year (cf. ESO Press Photo 11/97). In order to establish its true nature, she obtained its spectrum (in the visual to near-infrared region from wavelengths 450-1000 nm) on March 15 using the ESO 3.6-m telescope and the EFOSC1 spectrograph.

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And then - a Brown Dwarf! — Continued...

To her great surprise, the spectrum was of a type never seen before and certainly not that of a White Dwarf or any other easily identifiable type of star (cf. ESO Press Photo 12/97). In particular, there were no signs of spectral bands of titanium oxide (TiO) or vanadium oxide (VO) which are common in very cool stars, nor of the spectral lines seen in White Dwarfs. On the other hand, an absorption line of the short-lived element lithium was identified, as well as a hydrogen line in emission.

However, when the colour of this mysterious object was measured in different wavebands, it was found to be very red and quite similar to that of one of the two known Brown Dwarfs in double star systems. The presence of the lithium line in the spectrum is also an indication that it might be of that type.

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Searching for nearby faint stars — Continued...

The astronomer now decided to give the new object the name KELU-1; this word means `red' in the language of the Mapuche people, the ancient population in the central part of Chile. Its visual magnitude is 22.3, i.e. more than 3 million times fainter than what can be seen with the unaided eye.

In early April, additional infrared observations with the UKIRT (UK Infrared Telescope) on Mauna Kea (Hawaii) by Sandra K. Leggett (Joint Astrophysical Centre, Hilo, Hawaii, USA) confirmed the Brown Dwarf nature of KELU-1, in particular through the unambiguous detection of Methane (CH_4) bands in its spectrum.

The nature of Brown Dwarfs

Brown Dwarfs are first of all characterised by their low mass. When a body of such a small mass is formed in an interstellar cloud and subsequently begins to contract,

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The nature of Brown Dwarfs — Continued...

...its temperature at the centre will rise, but it will never reach a level that is sufficient to ignite the nuclear burning of hydrogen to helium, the process that it is main source of energy in the Sun and most other stars. The Brown Dwarf will just continue to contract, more and more slowly, and it will eventually fade from view.
This is also the reason that some astronomers consider Brown Dwarfs in the Milky Way and other galaxies as an important component of the `dark matter' whose presence is infered from other indirect measurements but has never been directly observed.

It is assumed that the mass limit that separates nuclear-burning stars and slowly contracting Brown Dwarfs is at about 90 times the mass of the giant planet Jupiter, or 8 percent of that of the Sun.

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KELU-1: a great opportunity for Brown Dwarf studies

Assuming that KELU-1 is identical to other known Brown Dwarfs, its measured characteristics indicate that it must be located at a distance of only 10 parsecs, that is about 33 light-years, from the solar system. Its temperature is obviously below 1700 degrees C (where TiO and VO condense as dust grains [3] so that the spectral lines of these molecules are no longer seen). Its mass can be no more than 75 times that of Jupiter, or 6 percent of that of the Sun.

During recent years, several Brown Dwarf candidates have been de-masked as low-mass stars and only recently a few Brown Dwarfs were identified in the Pleiades star cluster. Those Brown Dwarfs are quite young and therefore comparatively hotter and brighter.

Contrarily, KELU-1 is most probably somewhat older and its unique location so close to us greatly facilitates future investigations. Moreover, it is not at all `disturbed' by the presence of other objects in its immediate surroundings, as this is the case for all other known objects of this type.

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KELU-1: a great opportunity for Brown Dwarf studies — Continued...

It will now be important to obtain accurate measurements of KELU-1's parallax, that is, the small annual change of its position in the sky that is caused by the Earth's motion around the Sun and thus the viewing angle of an Earth-based observer. This should be possible within the next year.

Moreover, high resolution spectral investigations with large telescope facilities, soon to include the ESO Very Large Telescope at the Paranal observatory in northern Chile, will now for the first time enable us to investigate the processes that take place in the relatively cold upper layers of Brown Dwarfs. For instance, the observed presence of lithium shows that its atmosphere must be different from that of low-mass stars.

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KELU-1 and the `Dark Matter'

From the fact that KELU-1 is so faint that it was barely detectable on the ESO Schmidt plates, it is possible to estimate that the total volume so far surveyed for this type of objects by this research programme is rather small, only about 23 cubic parsecs (800 cubic light-years). A further consideration of the search statistics indicates that less than 10 percent of the Brown Dwarfs present in the surveyed volume would have been found. This translates into a local density of about 0.4 such objects per cubic parsec.

Although the mass density of Brown Dwarfs derived from this estimate is insufficient to constitute all the `dark matter' in the Milky Way Galaxy, it is consistent with the most recent estimates of the local mass density, both observed and as infered from dynamical considerations of the motions of stars in the solar neighborhood.

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Notes:

[1] This is done by means of a so-called blink-comparator, an optical device in which the two plates are placed. A tilting mirror allows to view the same sky field alternately on the two plates. Any celestial object that has changed its position will appear to `jump' back and forth and can thus be identified.

[2] A proper motion in the sky of 0.25 arcsec/year corresponds to a transversal speed of about 12 km/sec if the object is located at a distance of 10 parsec, or 32.6 light-years. The largest known proper motion of an object outside the solar system is that of Barnard's Star at about 10 arcsec/year.

[3] For instance, as the mineral perovskite.

Briton finds clues to rogue planet

Tim Radford, Science Editor
Guardian Unlimited
Friday October 8, 1999

A British astronomer believes he has detected a huge rogue planet disturbing comets at the edge of the solar system.

The object, far bigger than Jupiter, is at least 30,000 times farther from the sun than earth is, and any space probe would take thousands of years to get to it.

Though it is 10m times dimmer than the faintest star, John Murray, of the Open university, said last night he believed he had detected its influence, because of the way it sent comets tumbling towards a near orbit round the sun.

Astronomers have speculated for decades about a mysterious "planet X", a 10th member of the solar system. But this disrupter of comets could never have been part of the system originally, because it is so far from the sun. It may have been captured in some way, acting as an invisible disturber of the cosmic peace.

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Continued...

Three years ago Dr Murray began plotting the aphelion - the position farthest from the sun - of a set of comets that made rare visits and came from immense distances. He was struck by a pronounced "bunching" from a particular band of the heavens.

"The first thing I thought was: is there a big planet out there, like Jupiter, with its own family of comets? I plotted these things on a celestial sphere and they fell in a band, more or less a straight line."

The chances of 13 comets all from the same region being a coincidence, he calculated, was 1,700 to one. "Suddenly there was the evidence that there was an object out there."

Comets, leftover building blocks of the solar system, exist as a cloud of slowly orbiting debris on its rim.

Briton finds clues to rogue planet

Tim Radford, Science Editor
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Continued...

A few are dislodged and fall towards the sun in orbits of thousands of years. "What I'm suggesting is that this planet is going through this cloud all the time and is sending back these comets, and that is why you get this alignment."

Using only the circumstantial evidence of the comets, he was able to calculate an orbit, a distance and a position for the planet. Its motion is "retrograde" - it is travelling in the opposite direction to the other planets - and its plane is at a different angle.

His findings, first proposed three years ago, will finally be published in the monthly notices of the Royal Astronomical Society on Monday. Astronomers from the University of Louisiana have separately come to the same conclusions and will announce them to a meeting on the same day.

"Suddenly people are taking the idea a great deal more seriously than they were the day before yesterday," said Dr Murray. "If it really is there, where has it come from?"

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