Planet X - The Current Status

P. K. Seidelmann and R. S. Harrington
U. S. Naval Observatory

ABSTRACT. Neptune and Pluto were discovered because of predictions derived from the differences between the observations and ephemerides of Uranus, but Pluto wasn't the predicted planet and the discrepancies still exist. This continuing existence of systematic differences between the observations and ephemerides of Uranus and Neptune has led to predictions of a Planet X. The demise of the dinosaurs and the existence of comets have been cited as additional evidence for another celestial object.

Therefore, possible bodies have been hypothesized in the outer part of the solar system, or out beyond the solar system, including a binary companion, Nemesis. The theory of relativity and the incompleteness of the law of gravity have also been suggested as explanations for the outer planet discrepancies. Predictions of the possible locations of Planet X have been made, with rather large uncertainties, and selected searches of some regions have yielded nothing. IRAS and Pioneer observations exist as additional sources of useful observational data.

History

The planet Uranus was discovered by Herschel on 13 March 1781, because he detected that it was fuzzy, not stellar, in appearance, and it moved with respect to the stars. He was actually looking along the ecliptic for binary stars with large magnitude differences (Bennett, 1981). At the time it was thought faint stars were farther away than bright ones, and he hoped to find pairs in which he could see a small change in relative position due to parallax. After his discovery, it was determined that other astronomers had observed Uranus, but failed to detect that it was not a star.

On 1 January 1801 the first minor planet, Ceres, was discovered and many more continue to be discovered due to their rapid motion. To this day, there is not an accepted distinction between a principal planet and a

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minor planet.

In 1846, astronomy was significantly different from today. The ephemerides of the planets were of limited accuracy. There were no Palomar sky survey plates. Systematic star charts were not widely available. Photography was not in use, and the observational accuracies were significantly worse. The best tables for the motion of Uranus were those of Bouvard (1821). By 1832, Airy had reported differences between the observations and the tables for Uranus. Bessel (1824) had earlier pointed out errors in the tables of Uranus, and by 1840 he knew there were unresolved discrepancies and that an orbit and mass for an unknown planet should be determined. He was ready to start work on this project when ill health and then his death intervened.

On 10 November (1845), LeVerrier published his first paper on the investigation of the residuals of the motions of Uranus. A fortnight earlier Adams had communicated a prediction of the unknown planet to Airy. In response Airy inquired about the radius vector residuals. Adams, being a very young person, did not know how to respond to this nonsensical inquiry from the great Airy and did not. On 29 July 1846, Professor Challis at Cambridge began a search based on the prediction of Adams. Unfortunately, Professor Challis did not have a star chart or star catalog, so that he had to record the observations of the objects on multiple nights and try to determine whether one of the objects moved. Challis (1846) did not expect the prediction to be accurate and planned an extended search. After the discovery of Neptune Challis was able to determine that he had observed Neptune, but did not detect that it was the planet.

LeVerrier requested that Dr. Galle at Berlin look for the planet. LeVerrier's letter was received on 23 September 1846, and that night Neptune was discovered 55 minutes of arc from the geocentric position predicted by LeVerrier. While Galle could not detect that it was a planet from a disk-like appearance, he was able to use the Berlin Academy's Star Atlas XXI which had been printed in 1845. That atlas permitted Galle to recognize that he was observing an 8th magnitude star that was not included in the atlas.

Thus, both Adams and LeVerrier were able to predict the location of Neptune based on residuals of approximately 100 seconds of arc between the observed positions and predictions for Uranus. The discovery was dependent upon the availability of a star chart. Table 1 indicates the elements of the orbit of Neptune as predicted by Adams and LeVerrier and the elements determined by Walker (1847) after the discovery. The predictions were based on Bode's law to determine the mean distance. The prediction and discovery are in close agreement. Details of the discovery of Neptune are given by Airy (1846), Gould (1850) and Grosser (1979).

By the turn of the century the residuals in longitude of Uranus from LeVerrier's theory of 1873 reached a maximum of 5 seconds of arc, and

Table 1. Neptune Elements, Predictions and Actual

Elements		LeVerrier	Adams	Actual by Walker
a	(mean distance)	36.15	37.25	30.25
e	(eccentricity)	0.10761	0.12062	0.00884
i	(inclination)	*	*	1°54'54"
Ω	(longitude of node)	*	*	131°17'38"
ω	(longitude of perihelion)	284°45'	299°11'	0°12'25"
ρ	(period, in years	217.387	277.3	166.381
m	(mass, sun = 1)	0.0001073	0.000150	0.0000666
	(longitude 1847.0)	326°32'	329°57'	328°7'57"

* not predicted

the residuals in longitude of Uranus from Gaillot's Theory of 1903 (Gaillot 1910) reached a maximum 2 1/2 seconds. Therefore, Lowell (1915) predicted a planet beyond Neptune based on calculations. Pickering on the other hand preferred graphical means. Pickering (1928) used Uranus and Neptune to predict a Planet O. Pickering in fact predicted a number of different planets based on different combinations of the observations. Lowell's prediction was based on a planet six times the Earth's mass and much more distant from the Sun than Neptune.

At Lowell Observatory, after two unsuccessful earlier searches, an intensive search was initiated in 1929, with the work to be accomplished by Clyde Tombaugh. Plates taken on 23 and 29 January 1930 revealed the presence of a 15th magnitude object. The discovery of Pluto was announced on March 13, 1930, which was the 75th anniversary of Percival Lowell's birth and the 149th anniversary of Herschel's discovery of Uranus. Table 2 gives a list of the elements predicted for Pluto by Pickering and Lowell and the orbital elements of the discovered planet. Tombaugh (1961) went on to search for additional planets. The discovery of Pluto has been reviewed by Hoyt (1980), Tombaugh and Moore (1980), and Whyte (1980).

Since its discovery in 1930, the values, as accepted for general practice, for the mass and size of Pluto have decreased continuously (Duncombe and Seidelmann (1980)). With the discovery of the satellite of Pluto by Christy and Harrington (1978), the mass of Pluto was shown to be approximately 1/400th of the Earth's mass. Thus, Pluto was not capable of perturbing Uranus in a manner which Lowell or Pickering could have used to predicted its existence. Nevertheless, we are left with the puzzle as to why Pluto was discovered very near the locations predicted by both Pickering and Lowell (Table 2).
Figure 1 shows the relative positions of Uranus and Neptune during the period between the discovery of Uranus and the discovery of Neptune. There is symmetry, a conjunction and close proximity between the bodies during that time period.

During the period between the discovery of Neptune and the discovery of Pluto, Uranus made a complete orbit and Neptune was continually reducing

Table 2. PLUTO ELEMENTS, PREDICTIONS AND ACTUAL

Elements	P. Lowell 1915	W.H. Pickering 1919	Actual Pluto
Mean distance	43.0	55.1	39.5
Period, Years	282	409.1	248
e (eccentricity)	0.202	0.31	0.246
Long of Perihelion	204°	280°1	222°9
Date Perihelion	1991.2	1720.0	1989.9
Ω (longitude of Node)	-----	100°	109°6
i (inclination)	_____	15°	17°5
Long. 1930.0	102°7	102°6	108°5
Magnitude	12 to 13	15	15
Mass (Earth =1)	6.7	2	0.002

the separation (Figure 2). This geometric configuration should not lead to a good solution for the position of Pluto.

The observational evidence for Planet X

First, it must be recognized that the observational data have become progressively more accurate with time. The observations prior to 1900 are less accurate and show a bigger variation from observation to observation than the observations since 1900. The observations of Pluto, a fifteenth magnitude object and therefore 10,000 times too faint to be seen without a telescope, exist from 1914 to the present time, a period of seventy years out of an orbital period of two hundred and forty-eight years. These observations have an uncertainty of approximately one second of arc and cannot be used for investigating a tenth planet. The observations can be fit, but due to the short period of observations the predicted ephemeris will eventually differ systematically from the observations (Seidelmann et al (1985)).

The observations of Neptune cover the period from 1846 to the present time, approximately a hundred and forty years out of the hundred and sixty-five year period of Neptune. These observations have been and continue to be fit by ephemerides without difficulty. The puzzle is that approximately ten years after a prediction ephemeris has been calculated, the observations systematically differ from the prediction ephemeris. This has happened repeatedly since 1900 and it appears to continue to the present time (Newcomb (1898), Wylie (1942), Eckert, Brouwer and Clemence (1951),and Seidelmann and Duncombe (1982)).

The observational data for Neptune used in the JPL ephemerides DE 200 ended with 1978. Observations from the 6" transit circle of the U.S.

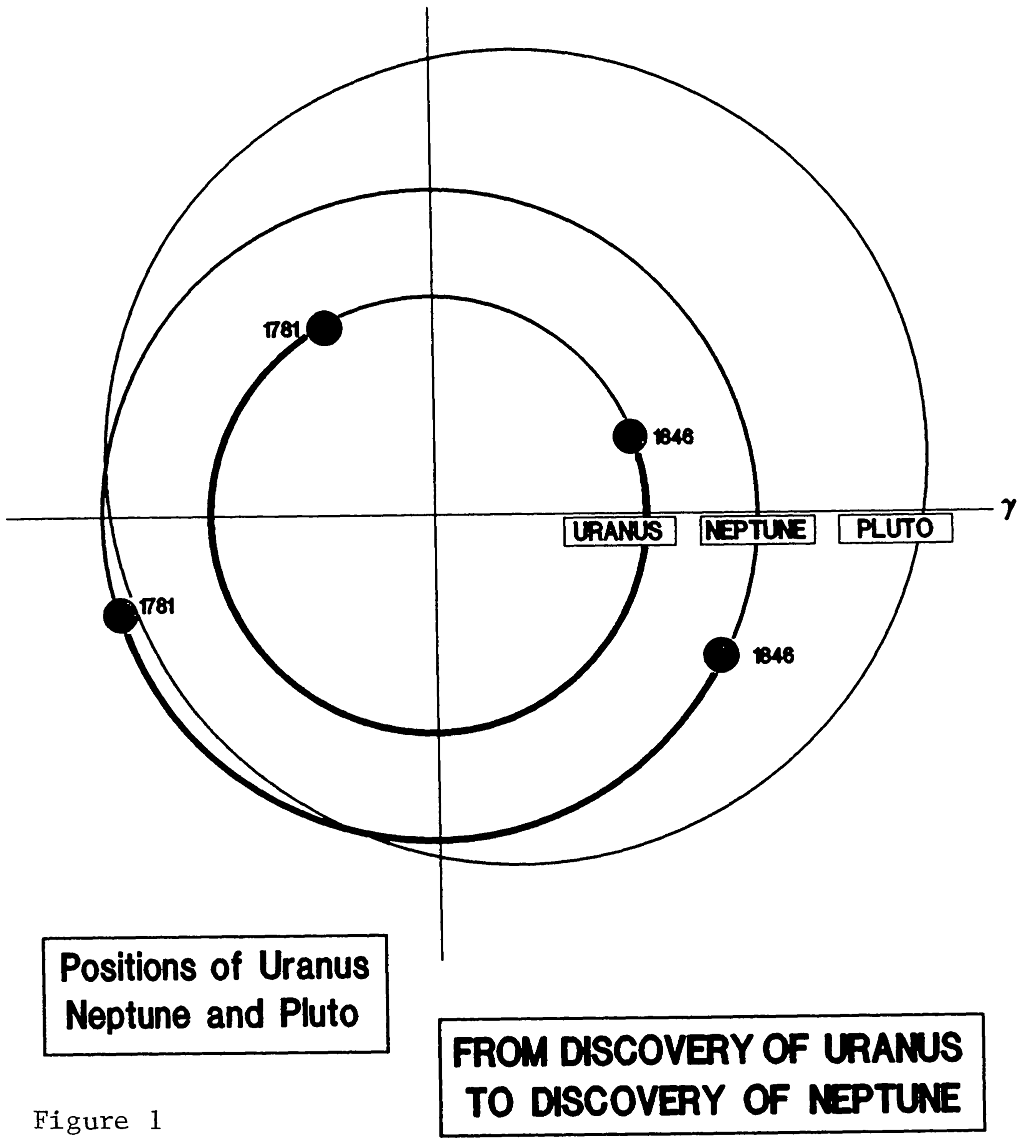

Figure 1

Naval Observatory through 1982 and the Carlsberg Meridian Circle at LaPalma through 1986, are now available and the systematic differences displayed by normal points are appearing again (Figure 3). The declination residuals do not show any systematic discrepancies. Why the prediction ephemeris is not good for a longer time period is not understood. Also, there are three prediscovery observations of Neptune, one in 1613 by Galileo (Kowal and Drake, 1980) and two in 1795 by Lalande. Possibly due to an uncertainty in the scale of Galileo's drawing, the Galileo observations cannot be successfully fit by any ephemeris; the formal discrepancy is 32 seconds of arc in right ascension and 40 seconds of arc in declination. For the Lalande observations (Mauvais, 1847), the differences in right ascension are approximately twelve seconds of arc while there are no differences in declination. Newcomb (1867) studied the Lalande observations and concluded that the probable error for the two observations is about 2".8 in right ascension and 1".5

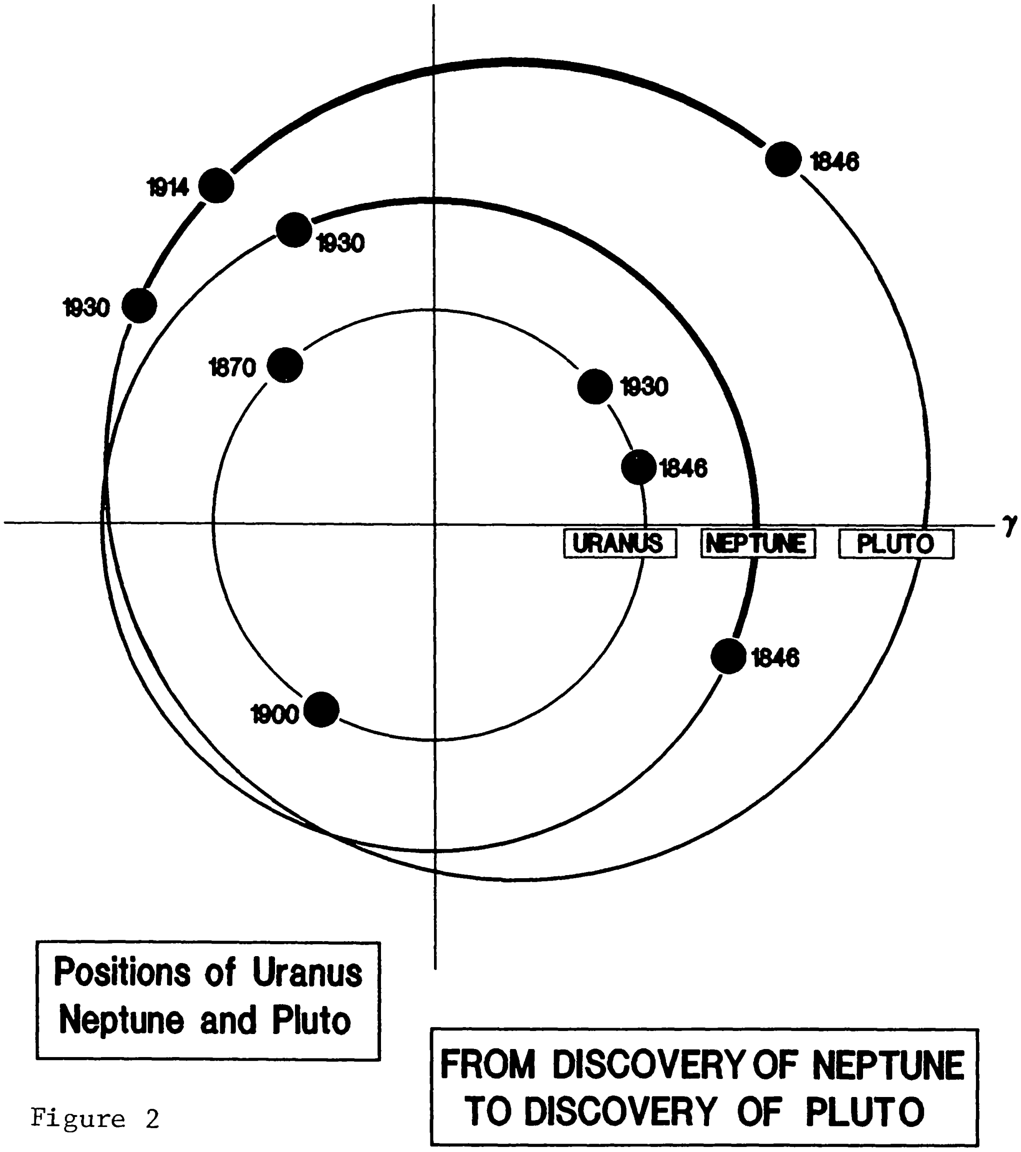

Figure 2

in declination.

The observations of Uranus cannot be accurately fit in right ascension when all of the observations are included in the solution. These observations, including prediscovery observations, extend from 1700 to the present (Seidelmann et al, 1985). Due to significant improvements in astronomy in the early nineteenth century, observations after 1830 are much more accurate than earlier ones. Since Uranus has an orbital period of about eighty years, almost two complete orbits are covered by that observational data. For DE 200 only one orbital period of data was used, because that way a prediction ephemeris could be determined to represent the current data. The use of the extended set of observations prevented a successful fit and differed from current observational data.

The question concerning this evidence is whether the observations prior

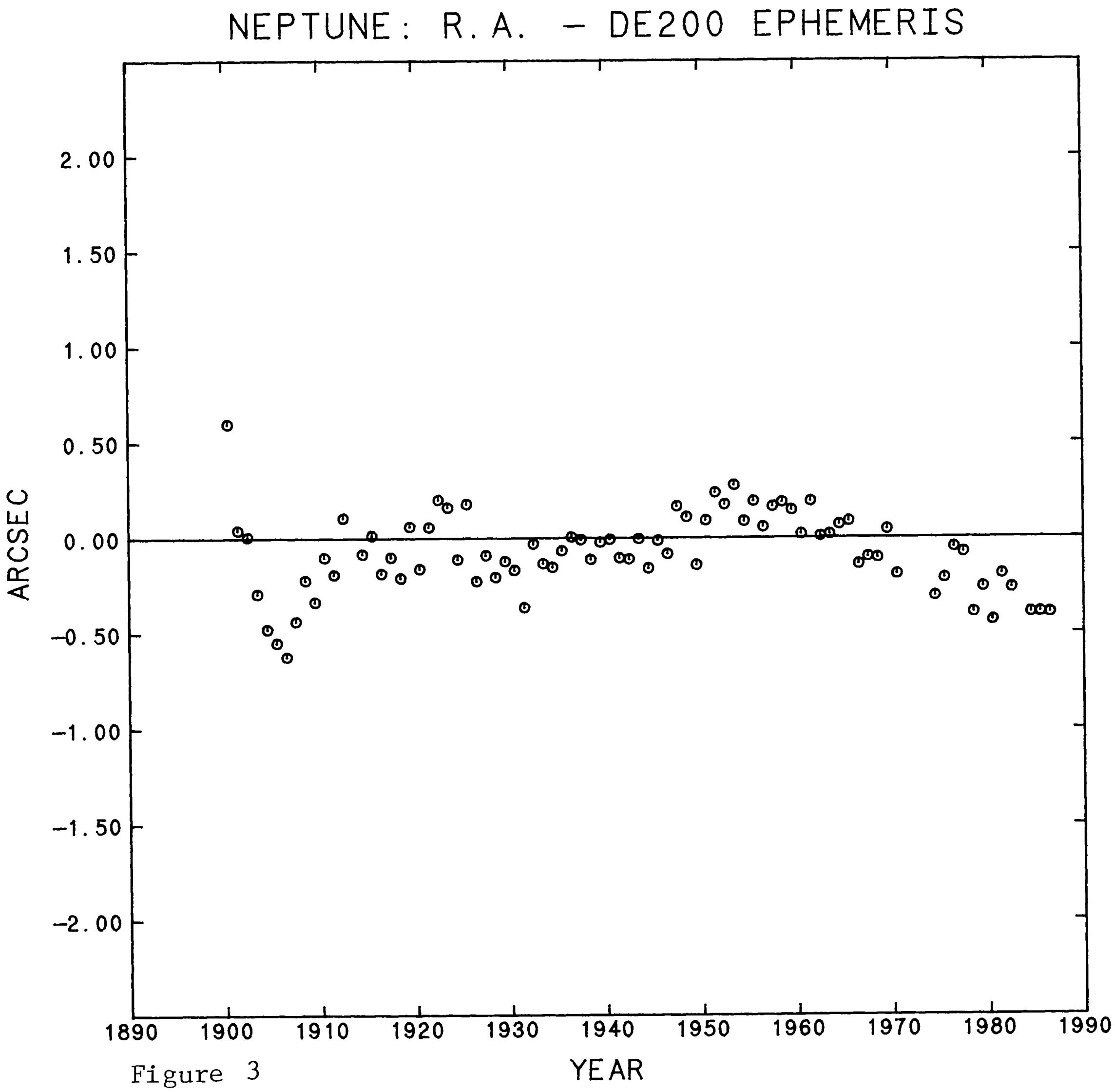

Figure 3

to 1900 could be subject to a systematic error that could be the cause of the difficulty, as opposed to the motion of the planet being affected by some external force. Possible sources of such systematic errors in the observations of Uranus could be its brightness, its motion, its size, a disk-like appearance in a telescope, and the observational methods prior to 1900. The Paris observations of Uranus were investigated by Corbin (1980) for systematic errors. While the scatter due to observational reduction procedures was greatly reduced the systematic discrepancies were not affected. Having fit DE200 to observations through 1978, more recent observations (1978-1982) show a systematic discrepancy as displayed by normal points in Figure 4. This indicates a discrepancy for Uranus similar to that of Neptune.

Other considerations that are sometimes brought into the discussion of the possibility of a tenth planet include the rapid disappearance of the dinosaurs and the corresponding appearance in dated core samples of Iridium in excessive amounts. This is explained as being due to unusual comet showers which were caused by Planet X disturbing the supply of comets in the inner Oort cloud (Whitmire and Matese (1985) and Matese and Whitmire (1986)).

Other possible mechanisms causing comets to enter the inner part of the solar system are nearby stars (Heisler, Tremaine and Alcock (1987)), and galactic tides (Morris and Muller (1986), Heisler and Tremaine (1986), and Torbett (1986)). Whether there was a much larger number of comets in the inner solar system at a given time is not known. Whether these comets impacted the Earth, providing the Iridium and changing the atmospheric conditions on the Earth enough to bring about the demise of the dinosaurs is not known. All these steps, disturbing the comets, impacting the Earth, changing the atmosphere, reducing the vegetation, and the

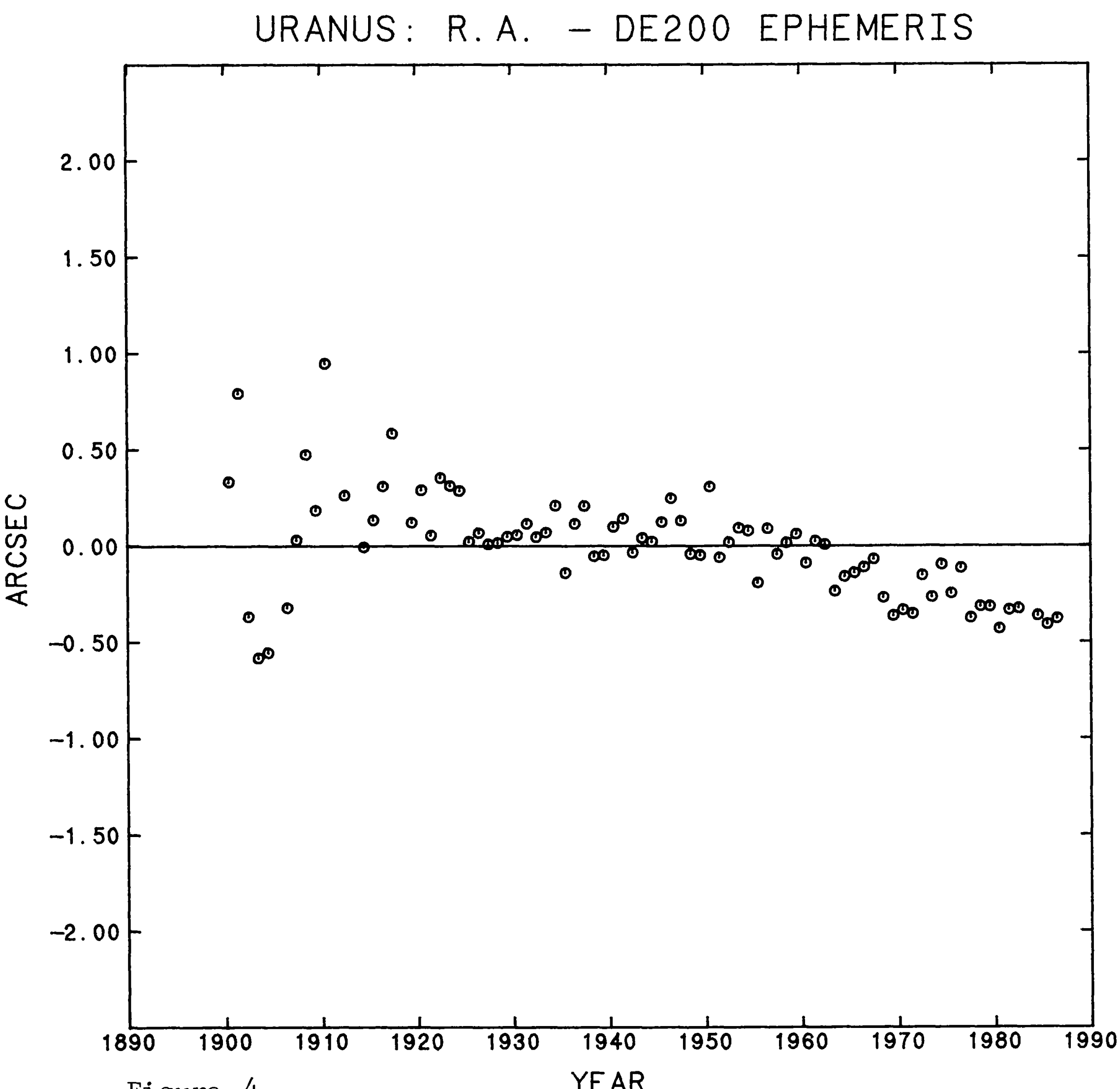

Figure 4

death of the dinosaurs, are hypotheses, not proven occurrences.

Another anomaly of the outer solar system is the satellite system of Neptune. Nereid's orbit is progade but quite eccentric while Triton's is circular but retrograde. Generally inner satellites are prograde and thought to be formed there and retrograde satellites, where they occur, are outer satellites and thought to be captured. Moreover, Pluto's perihelion distance is less than the mean distance of Neptune. At present, orbital resonances prevent the apse of Pluto's orbit from approaching the node, hence preventing close approaches between Neptune and Pluto, but this may not have always been so. Thus, there is a possibility that at some time something disturbed the satellite system of Neptune, or that there exists some event in the past history of Neptune and Pluto that explains their unusual motion.

There are also two Pioneer spacecraft traveling in different directions in the outer part of the solar system. As these spacecraft go further out into the solar system, they may have greater sensitivity to the distance, direction and mass of additional planets (provided, of course, they are traveling in the correct direction) (Anderson and Standish, (1986)). NASA, has recently announced that they have not detected any unexplained motion, from which they place constraints on the possible position of any unknown planet.

DISCUSSION

Let's consider the hypothesis that there is a Planet X out beyond Pluto. The effect of one planet on another is proportional to the ratio of the mass and to the inverse square of the distance. The observed effect is due to the differential of the force which is proportional to the inverse cube of the distance. The distance and mass, separately, cannot be unambiguously determined for a perturbing planet. Moreover, because angular velocity decreases with the distance, we cannot precisely determine its motion, nor its orbital period. The observational data, therefore, can only be used to determine an approximate location, mass and distance, or motion, for such a planet in the past. It is possible then to predict only in a very approximate way where a planet X could be at the present time.

The history of previous searches increases the probability of a planetary orbit moderately inclined to the ecliptic, for a planet brighter than seventeenth magnitude. However the lack of discrepancies in the declination observations argues for a planet close to the plane of the ecliptic.

Such a planet could explain the systematic differences in the observations of Uranus. It could improve our capability of predicting the motion of Neptune. Depending on its orbit, it might provide another piece in the puzzle of the motions of Neptune, its satellites, and Pluto.

Another hypothesis is called Nemesis, a star which is a binary companion to our Sun and in a very eccentric orbit with respect to our Sun (Raup and Sepkoski (1984)). Such an object could come close enough to perturb the comets and cause concentrations of comets to come into the inner solar system at certain times. It could also disturb the comets such that it would cause a continuing supply of comets coming at different times. If all these effects were correct, this could explain a shower of comets and the demise of the dinosaurs. Nemesis would have a very long orbital period, approximately 26 million years, so that its effect on the outer planets would be very slight over the two hundred year period. Rather, its principal effect would be on the barycenter of the solar system, or the point around which the Sun and the planets would move. The effect is sufficiently small, less than 0.1 milliarcsecond, that it probably could not be detected in the current observational data. Thus, Nemesis would not give us an explanation for the observed discrepancies in the motions of the outer planets. There are arguments against the Nemesis hypothesis, (Clube and Napier (1984), Hut (1984) and Hills (1984 and 85)).

Another possible hypothesis would be an incompleteness in our knowledge, or application, of the theory of relativity or the universal law of gravity. There is an old question concerning gravitational effects; are the effects instantaneous like a field effect, or is there a time delay which is proportional to distance? This has been considered a settled issue in favor of the field effect, but recent evidence from precise Earth-based measurements reopens the issue.

About 1900 it was recognized that there were discrepancies in the observed motion of Mercury. A planet inside of Mercury was hypothesized, and searches were made during eclipses of the Sun. A discovery was even claimed, although it was never confirmed. The explanation was General Relativity, which explained the observed motion of the perihelion of Mercury. Is the theory of relativity incomplete in some manner, or are there higher order terms which might affect the computation of the orbits of the outer planets? A difference in theories might explain the observed effects, but it is not likely that it would explain the appearances of comets nor the disappearance of the dinosaurs.

Planet X Predictions

Groups at the U.S. Naval Observatory in Washington and at Teledyne-Brown Engineering in Huntsville, Alabama, are attempting to solve for the orbit and present location of the planet. Observations of both Uranus and Neptune are now being used, although each has its limitations. These calculations for Planet X are much more difficult than those predicting Neptune from its effects on Uranus. The systematic variations that are now observed are much smaller than those of Uranus two centuries ago; in fact they are not much larger than the observational uncertainties. In addition, the orbital period of Planet X is expected to be much larger than that of Neptune, probably 500 years and possibly as much as 1000 years. This in turn requires a much longer period of observations.

There is also the problem that any solution actually produces two positions in opposite portions of the sky. Just as you can not tell if the Moon is overhead or underfoot, just because it is high tide, so there is an ambiguity in looking for missing planets. The resolution of this question depends on other things than which solution gives the best formal numerical result, such as the fact that one result puts the planet in the area searched by Tombaugh and the other does not. We also have the problem of still not knowing exactly the mass of Neptune, and thus it is much more difficult to apportion the influences of Neptune and Planet X on Uranus. The positions of Uranus, Neptune and Pluto in the last twenty years, the paths of Pioneer X and XI and the possible directions to Planet X are summarized on Figure 5.

The most recent predictions of Planet X by Harrington (1988), Gomes and Ferraz- Mello (1988), and Powell (1988) reflect the uncertainties. Harrington prefers the prediction in the region of Scorpius, while Gomes and Ferraz-Mello and Powell prefer Tauris.

Searching for Planet X

In 1929 Clyde Tombaugh began a search at the Lowell Observatory which resulted in the discovery of Pluto in 1930. He continued that search until 1943 covering a large part of the sky for objects as faint as 16th magnitude . There are various parts of the sky he did not cover and, of course, there is the possibility that the planet could be fainter than sixteenth magnitude. It must be remembered that there are some objects with matter much darker than normal. The satellite of Saturn, Iapetus, has a dark side and a light side. The rings of Uranus are much darker than expected. Comet Halley is darker than coal.

The infra-red astronomical satellite (IRAS) surveyed the sky looking for objects radiating in the infrá-red. Since this planet would be nearer than most other sources, warmer than other sources, it should appear relatively bright in the infra-red. The easiest way it would be detected however is by its motion with respect to the stars. The detectability of the motion of such a planet during the time between observations, and at the accuracy with which the positions could be determined, is marginal. The IRAS results have not discovered the existence of a tenth planet, but the data are still being studied.

The traditional ground-based search has not been forgotten. Astronomers at Lowell Observatory are now using the Teledyne results, and a survey has already been carried out from Palomar Observatory in California. Several small searches have been carried out from the Naval Observatory in Washington, and there is an effort underway at the Naval Observatory station at Black Birch in New Zealand. Obviously, nothing has been discovered so far, but there is a lot of sky to cover even with a good

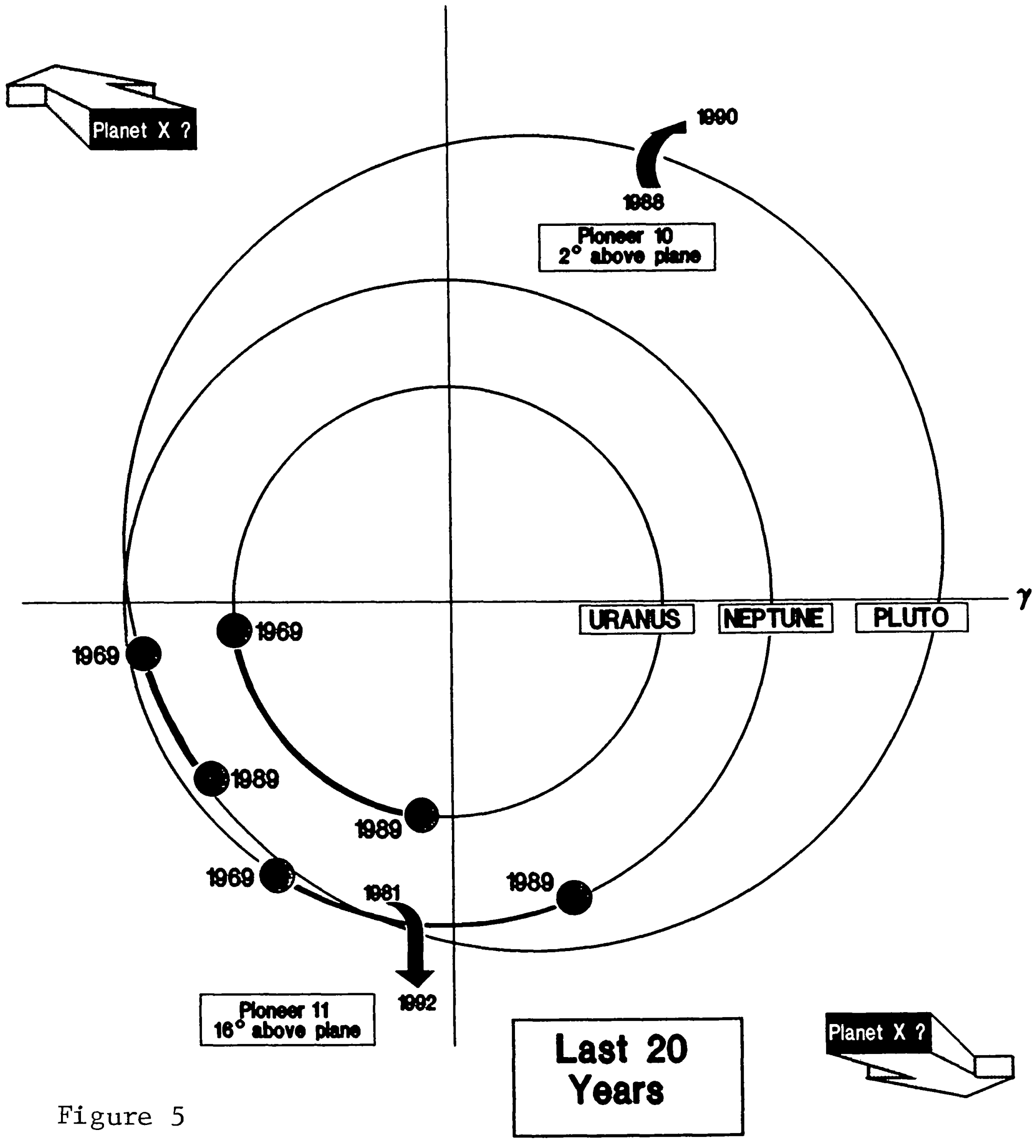

Figure 5

guess, and nobody thinks this is going to be an easy object to spot.

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