The Search for Planet X

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The Hunt for Planet X

This is a story that spanned over 200 years: from the discovery that Uranus was not following its predicted orbit and was thus presumably being perturbed by another, as yet undiscovered planet, Neptune, followed by the search for what Percival Lowell called "Planet X" that would lie beyond Neptune (where X means unknown), and finally the search for a tenth planet beyond Pluto (where X means ten as well). As we shall see, the search for a tenth planet effectively ended in August 2006 when Pluto was demoted from its status as a planet and the number of planets in the solar system was reduced to eight.

Uranus

Uranus was the first planet to have been discovered in modern times and though, at magnitude ~5.5, it is just visible to the unaided eye without a telescope it would have been impossible to show that it was a planet rather than a star, save for its slow motion across the heavens. Even when telescopes had come into use, their relatively poor optics meant that it was charted as a star many times before it was recognised as a planet by William Herschel in 1781.

William Herschel had come to England from Hanover in Germany where his father, Isaac, was an oboist in the band of the Hanoverian Foot Guards. As well as giving his third child, Freidrich Wilhelm Herschel, a thorough grounding in music he gave him an interest in the heavens. When 15, William entered the band as an oboeist and violinist and first came to England in 1755 when the Foot Guards were sent to help defend it from a feared French invasion. He soon returned to Hanover but in 1757, as the city was overrun by the French, he and his brother Jacob came to England for a second time. Jacob returned to Hanover to take up a position in the court orchestra but his brother, who had anglicized his Christian names to Frederick William, stayed to take up the position of instructor to the band of the Durham Militia.

Following a short period as a concert manager in Leeds he was offered the post of organist at the Octagon Chapel in Bath where he set up home. After some years he was able to persuade his family to allow his sister Caroline to come to Bath to act as his housekeeper. She had been acting as a servant in her father's house and William had to pay his father an allowance so that he could pay for a replacement! She repaid William's kindness with great devotion, giving up a career as a singer in order to assist him, and later became a significant astronomer in her own right.

William's interest in astronomy increased and he became very unsatisfied with the telescopes that he could buy so decided that he would make a reflecting telescope of his own. In those days, the mirrors were cast in speculum metal ' an alloy of two parts copper and one of tin ' and he made the castings in the kitchen of his house. Occasionally the mould would break and the molten metal would crack the stone floor.

By 1778, he had built an excellent telescope having a mirror of just over 6 inches (150 mm) in diameter and began to make a survey of the whole sky. On the night of 13th March 1781 he observed an object that did not have the appearance of a star and he first thought that it was a comet:

Replica of the telescope with which William Herschel discovered Uranus

'The power I had on when I first saw the comet was 227. From experience I know that the diameters of the fixed stars are not proportionally magnified with higher powers, as planets are; therefore I now put the powers at 460 and 932, and found that the diameter of the comet increased in proportion to the power, as it ought to be, on the supposition of its not being a fixed star, while the diameters of the stars to which I compared it were not increased in the same ratio. Moreover, the comet being magnified much beyond what its light would admit of, appeared hazy and ill-defined with these great powers, while the stars preserved that lustre and distinctness which from many thousand observations I knew they would retain.'

Observations over the following months showed that it did not have the highly elliptical or parabolic orbit of a typical comet and that it was in a nearly circular orbit having a semi-major axis of just over 19 AU.

It soon became apparent why Herschel had seen that that it was a planetary body whilst others had not. Side by side comparisons with telescopes in use by others confirmed its far higher image quality - Herchel had proven to be a superb telescope maker! Uranus has a maximum angular size of 4.1 arc seconds and, as the author has observed with an excellent telescope just a little smaller than Herschel's, it appears as a tiny greenish-blue disk. But unless a telescope has well figured optics this disk would be very hard to distinguish from a star. The fact that the new planet had been charted, if not recognised as a planet, many times over the previous century allowed an accurate orbit to be computed and, later, this was to be a major factor in the discovery of Neptune.

Herschel quickly received acclaim and was made a Fellow of the Royal Society. The new planet became known as Uranus despite Herschel's wish for it to be named Georgium Sidus (George's star) after the King of England - a fellow Hanoverian. In 1782 Herschel demonstrated his telescope to the King and soon received a royal pension to allow him to devote himself exclusively to astronomy. Five years later Caroline, who had become his observing assistant, also received a royal pension. To supplement their royal income Herschel made and sold telescopes including a 25ft long telescope that he made for the Madrid Observatory and for which he received £3000. In today's money this would be equivalent to at least £100,000!

Neptune

Neptune, at ~8th magnitude, can be seen in even a small telescope and had even been observed by Galileo. Whilst observing Jupiter on the 28thDecember 1612 he recorded Neptune as an 8th magnitude star and a month later observed it close to a star on two successive nights. He noted that their separation had changed and could easily have reached the conclusion that this was because one was not a star but a planet! It was later observed by John Herschel, William's son, who also believed it to be a star.

The final discovery of the planet Neptune is one of the most interesting stories in astronomy with its position being predicted independently by two mathematicians, John Couch Adams at Cambridge, and Urbain Le Verrier at the Paris Observatory. This resulted from a key fact about Uranus: its magnitude (which varies between 5.3 and 5.9) had meant that it had been observed many times prior to the realisation that it was a planet by William Herschel. John Flamstead had observed it several times from 1690 and allocated it the name 34 Tauri and it was recorded several times between then and its eventual discovery as a planet and the French astronomer, Pierre Lemonnier, observed Uranus at least twelve times between 1750 and 1769. These so called 'ancient observations', when combined with the more accurate observations made after its discovery as a planet, meant that an accurate orbit for Uranus could be immediately calculated. However by 1821 it had become obvious that Uranus did not appear to be following its predicted obit accurately and the thought arose that its orbit might be being perturbed by an, as yet undiscovered, planet that lay beyond Uranus.

John Couch Adams had studied at St John's College in Cambridge and graduated in 1843 as the 'senior wrangler', the best mathematician in his year. He was elected to a fellowship of his college and decided to devote his study to the resolution of the problem of the orbit of Uranus; believing it to be due to a more distant planet. He derived a solution in September 1845 and, it is thought, gave it to the Professor of Astronomy at Cambridge, James Challis. On the 21st of September he visited the home of the Astronomer Royal, George Airy but, failed to find him in. He tried again on October 21st but Airy was having dinner and would not see Adams who then left a manuscript giving his solution. Airy found this difficult to follow and sent a letter to Adam's requesting some clarification of the details, but it appears that Adams failed to reply ' possibly because he had been upset at Airy's refusal to see him..

Meanwhile in Paris, Le Verrier, who had been asked to look at the problem by his director, had also derived a position for the planet. Perhaps because he was not well liked, there appears to have been no serious attempt to follow up on his prediction at the Paris observatory and Le Verrier sent it to Airy. Airy realised the similarity of the predicted positions of the proposed planet and so, in July 1846, asked Challis (at Cambridge) to make a search for it. Unfortunately, Challis did not have a detailed star chart for the region where it was hoped that the new planet might be found so began to make one. If he then re-observed the positions of all the objects that he had charted, he would be able to spot the predicted planet by the fact that it would have moved slightly against the background stars.

John Couch Adams and Urbain le-Verrier

On the 18th September Le Verrier wrote to Johann Galle at the Berlin Observatory asking them to make a search. Galle received this letter on the 23rd September and his colleague, Heinrich d'Arrest, pointed out that they had a newly observed star chart for the appropriate region of the sky and thus they could easily spot the planet if it were present in the field. They made the observation that night and it took just 30 minutes to locate the planet just one degree away from Le Verrier's position!

In fact Challis had noted on the 29th of September that one of 300 stars that he charted that night had showed a disk - just as a planet would - but, being a cautious man, had waited for further observations to show its motion through the stars. He had not been able to make them before the announcement of the planet's discovery in the Times newspaper of the 1stOctober 1846.

William Lassell, who had made a fortune in the Brewery trade in Liverpool, had built a 24 inch telescope and immediately made observations of the new planet in the hope of finding any satellites. He started his observations on the 2nd October and on the 10th of October discovered Neptune's moon Triton.

The honour of Neptune's discovery is now shared by both Adams and Le Verrier. It is interesting to note that their predictions of Neptune's orbit were not that good and that for only about 10 years, from 1840 to

1850, did their predictions agree reasonably well with Neptune's actual position. More recently, the discovery of some papers that had been 'misappropriated' from the Royal Observatory at Greenwich cast some doubt on Adam's claim and perhaps he does not deserve equal credit with Le Verrier.

With hindsight, it is actually quite easy to predict where Neptune was to be found. The diagram of Neptune and Uranus has been drawn in a rotating co-ordinate frame so that Neptune appears fixed in space. As Uranus is both orbiting the Sun more rapidly and its orbit has a shorter circumference, it will pass Neptune 'on the inside track'. You will see that, as Uranus nears Neptune, the gravitational force between them will tend to advance Uranus in its orbit, so it will appear ahead of where it would be expected to be. (The solid disk, rather than the open circle.) Once Uranus has passed beyond the position of Neptune, their mutual gravitational attraction will slow Uranus down so that, eventually, it will have regained its expected position. One can see that Neptune should lie beyond the position of Uranus when Uranus is furthest ahead of its predicted position.

The orbit of Uranus in a frame of reference in which Neptune is stationary.

Pluto

The discovery of Pluto followed on from that of Neptune. Neither the orbits of Uranus nor Neptune were well defined, and it was suspected that there might be a more distant planet that was affecting their orbits - called 'Planet X' by Percival Lowell of Mar's fame. In 1905 he had predicted its position and began a photographic search at the Flagstaff Observatory. Nothing was found and following more refined calculations began a further search in 1914. He and the staff of his observatory continued the search without success until his death in 1916. Though Pluto did actually appear on some of the plates taken on March 19th, 1915 it was not recognised as such as the object was far fainter than expected.

Due to problems with Lowell's will following his death in 1916, the observatory virtually ceased to function until 1929 when its then director, Vesto Melvin Slipher, began a new search. A young amateur astronomer, Clyde Tombaugh, had sent Slipher drawings that he had made of Jupiter using his Newtonian telescope in the hope of being offered a job. These impressed Slipher, and he employed Tombaugh to take images with the observatories 13 inch astrograph ' essentially a wide field camera.

Clyde Tombaugh with his home-built telescope along with drawings he made of the planet Jupiter.

Two images taken some time apart were then compared in what is termed a 'blink comparator' in which the images are rapidly viewed in turn. Any object that has moved in the time between the two exposures would appear to jump in position whilst the stars would remain fixed. This allows planetary bodies to be rapidly located. The initial search for planet X was unsuccessful so Tombaugh began his own search.

From a pair of plates taken in January 1930, Tombaugh discovered a new planet on the 18th of February. The motion of the planet was confirmed in follow up observations and on the 13th of March 1930 its discovery was announced. Its name was suggested by Venetia Burney, the 11 year old daughter of an Oxford Professor, when she was told of its discovery the next day. Pluto was the Roman God of the underworld who was able to make himself invisible. As the first two letters of its name were the initials of Percival Lowell, at whose observatory it had been discovered, this suggestion was eagerly accepted.

Initially it was thought that Pluto had a significant size - even though it could only be observed as a point "star-like" object showing no angular size. It would have had to have a substantial mass to explain the perturbations in the orbits of Uranus and Neptune. With lobbying from the Lowell Observatory it is not surprising that it was given the status of a planet. There is a way to estimate its size. This can be done by assuming its "albedo" - the amount of sunlight that is reflected from its surface. For example, Venus with is totally covered by cloud has a high albedo of 0.65 meaning that it reflects 65% of the light falling on it, the Earth, which is partially cloud covered, has an albedo of 0.37 and Mars has an albedo of just 0.15. At the bottom end of the scale, Mercury and the Moon have albedos of just 0.11 and 0.07 respectively. Objects in the asteroid belt have low albedos, down to about 0.05, whilst a typical comet nucleus has an albedo of 0.04. At the other end of the scale, Enceladus, a moon of Saturn, has one of the highest known albedos of any body in the Solar system, with 99% of the light falling on it being reflected.

The apparent magnitude of a body will thus depend on its distance, its size and albedo so as we know Pluto's distance and if we assume its albedo we can estimate its size. Even initially, taking a mid range albedo, it did not appear that large and, using a typical planetary density, would not have had enough mass to give rise to the assumed perturbations of Neptune's orbit that gave rise to Lowell's prediction of Planet X.

Given enough time, there is a method that will give an accurate measure of the size of a planet: sometimes a planet will pass in front of (occult) a star and the length of the occultation will depend on the distance of the planet from the Sun, its diameter and how near centre of the planet passes over the stars position. So there will be a maximum length of occultation and from many such observations this maximum will be found and hence the diameter of the planet. Occultations of Pluto are rare, but it soon became apparent that it could be not that large. By 1955, Pluto's estimated mass had reduced to roughly that of the Earth, with further calculations in 1971 bringing it down to that of Mars. (At that rate, Pluto would soon cease to exist!)

A key discovery in 1976 found that Pluto's surface reflection signature matched that for methane ice and would hence have a high albedo of ~0.66, equivalent of that of Venus. Thus Pluto was exceptionally luminous for its size and this, of course, reduced its estimated size. Putting in a reasonable density, Pluto could not be more than 1 or 2 percent the mass of the Earth!

Charon

In the 1970's, James Christy had been making planetary observations at the Naval Observatory in Washington in order to refine their orbital parameters. He had been rejecting some images of Pluto as they had appeared somewhat elongated. This effect, as the author knows to his cost, usually appears when the telescope is not tracking correctly and images 'trail' so becoming elongated. However he noted that firstly that the star images in the photographic plate were perfect - indicating that the telescope was tracking correctly - and secondly that the extension of Pluto's image appeared to move around Pluto as time went by. It transpired that Christy was observing the motion of a satellite, now called Charon, orbiting Pluto, and its discovery was announced on June 22nd1978. In 1990, the Hubble Space Telescope was able to image the two separate disks of Pluto and Charon. Charon was the ferryman who carried the dead across the river Styx and had close ties to Pluto so was an ideal name. Its first 4 letters were also the same as those of Christy's wife Charlene!

If the period and semi-major axis of a satellite are known, it is possible to calculate the mass of the planet around which it is orbiting. For the first time, it became possible to accurately calculate the mass of Pluto which was found to be just 2% that of the Earth. This was far too low to have had the effects on the orbits of Uranus and Neptune by which its existence had been first predicted. Pluto is thus smaller and much less massive than the terrestrial planets and, with a mass less than 20% that of the Moon, it is also less massive than six other moons: Jupiter's moons, Ganymede, Callisto, Io and Europa, Saturn's moon, Titan, and Neptune's moon, Triton. Observations of mutual occultations between Pluto and Charon also allowed an accurate measurement of its diameter to be made, which is close to 2300 km. Pluto is thus more than twice the diameter and a dozen times the mass of Ceres, the largest object in the asteroid belt.

In 2005, two further moons of Pluto were discovered, now called Nix and Hydra.

Appropriately, Nix was the goddess of darkness and night and the mother of Charon.

Hubble Space Telescope image of Pluto with its three moons

On January 18th 2006 a spacecraft called New Horizons left the Earth for a 9 year voyage to Pluto and beyond. New Horizons passed Jupiter in February 28th, 2007 using the planet's gravitational field to increase its speed to around 83,000 km/hr (in what is called a slingshot manoeuvre) and, having flown over 3 billion miles, will flyby Pluto and Charon in July 2015 before hopefully visiting some more distant Kuiper belt objects in an extended mission.

The search for a 10th Planet

Following the impacts of the fragments of the comet Shoemaker-Levy 9 into Jupiter in July 1994, leaving scars on its surface larger than the size of the Earth, governments became very aware of the threat to the Earth that comets and asteroids might pose. They thus funded observing projects that would identify the so called "near-Earth objects" (NEOs) in the hope that we could identify those that were a threat to us in sufficient time for measures to be taken to avert an impact.

The technique is essentially quite simple. Two photographs are taken some time apart (~1 hour) of the same region of the sky. Assuming the telescope is tracking the stars accurately, stellar images will be point-like but, due to their motion round the Sun, asteroid images may appear slightly extended and, of course, they will have moved in position between the two images. In the early days of such searches, the two images were viewed together in a blink comparator - such as that used by Tombaugh when he discovered Pluto - when each image is viewed alternately and an object which has moved will appear to "hop" back and forth so making it stand out against the background stars. An alternative approach, as used by Carolyn Shoemaker in the Shoemaker's searches for NEOs, was to observe the two images as a stereoscopic pair. An asteroid would then appear to "float" above the stars. This was obviously very time consuming but, using a Schmidt telescope that could image areas of sky several degrees across at a time, a reasonable area of sky could be covered each night of observations.

Ice Dwarfs

Technology then moved on to the point that a totally computerised digital solution to the problem could be found by the use of large CCD arrays. Two "digital images" taken some time apart could be compared by a sophisticated computer program to spot any motion. The further away from the Sun, the less the positional change between the two exposures. This technique has enabled many hundreds of asteroids to be discovered along with comets and, excitingly, what have become known as "ice dwarfs" lying beyond the orbit of Neptune. This term is used as they are predominately made up of ice. They are also correctly termed "trans-Neptunian objects" or even "Kuiper belt objects" as this is the name given to a wide region lying beyond Neptune.

The first large ice dwarf was discovered by Bob McMillan using the 90 cm University of Arizona's Spacewatch Telescope. It was named after the Hindu god Varuna and initially thought to be about 900 km in diameter. Not long after Ixion was discovered, thought to have a diameter of 800 km. The only way that their diameters could be estimated was to guess at their albedos, assumed to be about 0.5. It now appears that these objects have higher albedos (~0.7) than initially thought and thus their sizes are less - the most recent estimate for Varuna's diameter being 500 km.

In October 2001, following several years work, a superb instrument saw first light. It comprised the 48" Samual Oschin Telescope on Mount Palomar (a Schmidt telescope with a very wide field of view) with a new 50 million pixel CCD array called NEAT, the Near Earth Asteroid Tracking camera. Though its prime purpose was to detect NEOs, not long afterwards, in January 2002, Mike Brown and his colleagues at Mount Palomar discovered a further ice dwarf with a diameter estimated to be ~800 km and in June that year discovered an object with possibly an even greater diameter. The Hubble Space Telescope was able to image a tiny disk which showed that its diameter was 1250 km - half the size of Pluto! This was far larger than had been expected. It turned out that the object was not ice covered and had an albedo of just 0.1 so, to give the observed brightness, had to significantly larger than those with albedos of ~ 0.7. It was given the rather special minor planet designation MP 50,000 and then named after a god of the Native American Tongva people, Quaoar. Quaoar has an orbital period of 287 years and lies at a distance of 6.5 billion km from the Sun. Unusually for such objects, its orbital plane is only eight degrees away from that of the solar system.

It surely couldn't be long before an object would be found that rivalled Pluto and it was not long in coming! A new camera with an matrix of 161 CCD arrays giving a total of 161 million pixels was mounted on the 48" Schmidt enabling each observation to cover 10 square degrees of sky and the search continued. Each target area was observed three times at 1.5 hour intervals. In this time, a Kuiper belt object would have moved an angular distance of typically 2-4 arc seconds. The software thus searched the image data for objects that moved this distance between each pair of observations. The team gained success on the very first night of observation when an object ~700 km in diameter and named 2003OP32was discovered. As the year went on, the discovery of ice dwarfs became almost routine and by the February of 2004 more than 30 had been discovered. On February 19th, the team announced the discovery of 2004DW, later given the name Orcus, a Roman god of the underworld. This had an estimated diameter of 1,600 km, even bigger than Charon, Pluto's moon.

Sedna

2003VB12, as Sedna was initially called, was discovered from images made in November 2003 and found to have a very elongated orbit. When discovered it was ~11 billion km from the Sun, nearly as distant as Pluto, but when furthest away it would be 146 billion km, 975 AU and 24 times the average distance of Pluto! Its orbital period was 12,000 years. Sedna, with a diameter of ~1800 km, was the largest object to have been found in the solar system since Pluto - so surely an object larger than Pluto would be discovered before long. Though Mike Brown did not know it at the time, that object already existed on the hard disks of his computers.

2003UB313

If an object was very far out beyond Pluto, its movement across the sky would naturally appear less. To avoid false alarms, the software would not detect objects that moved less than 1.5 arc seconds per hour across the sky. So Brown's software would reject any objects beyond 12 billion km - Sedna had only just been caught. He therefore reduced the threshold for detection and all the images were reprocessed. Rather embarrassingly, they found an ice dwarf that really should have been detected earlier. It was initially nicknamed "Santa" as it had been found on December 28th. Santa is egg shaped, rotates rapidly and has a small moon.

Just eight days later, Brown found three more ice dwarfs. Two, K31021A and K31021B, were faint but the third, K31021C, was much brighter. It only moved 1.4 arc seconds per hour, implying great distance, and was determined to lie 97 AU or 14.5 billion km from the Sun - almost three times further away than Pluto! To appear so bright at such a distance implied that it must be very large, probably larger than Pluto. Perhaps Planet X had been found! Brown's team already had a name ready for an object that they suspected was the tenth planet and it obviously should begin with an X. They had chosen Xena, the name of a warrior princess who had first appeared in comic books in the 1990's and then in her own television series - of which the team had pleasant memories.

When discovered, Xena was at the furthest point of its orbit and, with a period of 557 years will not be closest to the Sun for 275 years when it closes to a distance of 5.6 billon km. Its orbit was inclined at 44 degrees to the plane of the solar system - not, sadly, a good start for it to be classed as a planet. Brown and his colleagues did not really believe that Pluto should be classed as a planet either. However, it was immediately apparent that it must be larger than Pluto. Given its observed brightness and known distance and assuming it reflected 100% of the light that falls upon it (an albedo of 1) it would have the same diameter as Pluto. To account for its observed brightness given the typical albedo of an ice dwarf of ~0.7 it would have to be somewhat larger than Pluto.

Soon after the following Easter a third bright object, K50331A, was found. Brown nicknamed it Easter Bunny. Together with Santa and Xena and along with Pluto, it was one of the four brightest objects known in the outer solar system. At some point their existence had to be made known to the world. They decided to present Santa to the world at the beginning of September 2005 with, the jewel in their crown, Xena, to be announced a month later. On July 20th, an abstract of their paper, using the code K40506A for Santa, was published on the website of the conference at which they were to reveal its details. But this was not to be.

On the morning of July 25, five days later, Pablo Santos-Sanz was studying plates taken 2 years earlier with a small 36 cm telescope located in southern Spain and operated by the Andalusian Astrophysics Institute in Grenada. On Wednesday 27th July he reported its discovery to the Minor Planet Centre (MPC), the international centre for recording such discoveries and reporting them to the astronomical community. The Minor Planet Centre then received more detailed data on the object that had been obtained from archived digital images recorded by the Near-Earth Asteroid Tracking Program and further confirmatory observations that had been made on the 28th July with a 30 cm robotic telescope on Majorca. This showed that it really was an exceptional object and the MPC announced to the world as 2003EL61 as it had first appeared on images dating from March 2003.

Scooped!

As he read of its discovery, Mike Brown realised that it had exactly the same orbit as his ice dwarf, Santa -

the brightness and position were identical. Twenty minutes later he received a concerned e-mail from Brian Marsden, director of the MPC. Another astronomer, Larry Wasserman, had seen the similarity between 2003EL61 and the object K40506A referred to in Brown's abstract. Could they be the same, and had the information about K40506A leaked in some way' Brown replied that no such information was available, but later that evening entered K40506A into Google. To his amazement and alarm, the search brought up a page of the observing log of the Kitt Peak Observatory telescope that he had been using to make follow up observations of Santa - giving the date, time and, most significantly, its position. It later transpired that the same computer that had sent the discovery e-mail to the MPC had accessed the critical observing logs three times on the morning of July 26th - the day before the Spaniards announced its discovery.

Even worse, the positions of Easter Bunny and Xena could be found in the same observing log. Their discovery could perhaps be announced by others before his team and so take away the kudos for the discovery of what might well become the 10th planet. A press release was quickly put together under the title "NASA Funded Scientists Discover Tenth Planet" and Xena was announced to the press on July 29th, 2005. It was later found that Xena had a moon, initially called Gabrielle.

Xena and Gabrielle (the warrior princess's companion)

Its discovery put Brian Marsden into a quandary. For a major discovery such as this, the IAU's Committee on Small Body Nomenclature could decide on a formal name for Xena within a day. The problem was that if it were just an ice dwarf, the committee could name it, but if it were to be classified as a planet they would have no say in the matter. This made the question of what was or was not a planet even more pressing. Though attempts, as we will see, were being made by the IAU to resolve this problem at the time, no definition had been agreed upon.   The time had come to decide.

What is a planet?

With an increasing number of "Ice Dwarfs" being found beyond Neptune it had becoming increasingly obvious that, before long, an object larger and more massive than Pluto would be found. But what constituted a planet'

The concept of a "planet" had never been clearly defined:

Is the fact that it orbits the Sun sufficient'

- no as all asteroids, comets and even dust particles would count.

Must it have an atmosphere'

- no, if so, Mercury would not count.

Must it have satellites'

- no, if so, Venus would not be a planet.

Must it have a minimum size'

- if this were set at 2000km, Pluto would count, but isn't this a bit arbitrary'

The thorny question reared its head at the 24th triennial meeting of the International Astronomical Union (IAU) at Manchester in 2000. Mike A'Hearn gave a lecture entitled "Pluto - planet or trans-Neptunian object'" Others objected and proposed a definition which would include Pluto. In their view, to be a planet, an object must orbit the Sun and be sufficiently large that gravity would have caused its shape to be approximately round. If a body is made of rock this requires a minimum diameter of ~700 to 800 km. They made a distinction between the eight "solitary" planets (Mercury to Neptune) - uber-planets - which had diameters greater than 700 km and the much larger category of smaller objects - unter-planets. Their proposal was not that clear with sub-catagories and qualifications and, perhaps not surprisingly, was not adopted.

The Hayden Planetarium

When the prestigious Hayden Planetarium in the American Museum of Natural History in New York came to mount a brand new solar system exhibition, its Director, Neil deGrasse Tyson, decided that Pluto would have no place in it - the Solar System would only have eight planets and that Pluto was just one of countless ice dwarfs that lay beyond Neptune. When the New York Times highlighted this fact on January 22, 2001 there was an outcry both from the public and some well known scientists. In many ways Pluto was a favourite amongst young people, not least because Micky Mouse's dog Pluto had been given that name following its discovery. (Micky's dog had first been called Rover and only became Pluto in The Moose Hunt which premiered on May 3rd 1931.) Tyson stuck to his guns and the exhibition went ahead unchanged!

IAU Action

When the discovery of Sedna, which was suspected to have a diameter of 1,800 km, was announced in 2004, the IAU finally took some positive action and set up a committee to define what was, and was not, a planet. The 19 members of the committee never actually got together and their deliberations were conducted by e-mail. All efforts to get them to agree failed - partly as historical and cultural considerations rather than pure scientific ones played an important part. To confound the problem, after a year of unfruitful discussion, 2003 UB313 had been discovered. Xena, as she was then called, was likely to be larger than Pluto. The committee came to no firm conclusions and was quietly disbanded. There then arose a problem about the naming of this new object. If it was not a planet, one committee of the IAU would be responsible to give it a name, if not, another. There was stalemate. The IAU then placed Pluto's fate into the hands of a small panel of just seven members who were asked to provide a proposal that would be debated at the 2006 IAU General Assembly in Prague.

Things didn't quite go according to plan. The committee met in complete secrecy and had a final meeting on June 30th, 2006. It was held at the Paris Observatory where, rather nicely, Le Verrier had predicted the location of what was to become the planet Neptune - would Neptune become the outermost planet' Discussions that day could not come up with a suitable definition but, on the following day, they succeeded in producing a draft resolution that would be debated on the last day of the IAU meeting in August. Its contents were initially kept secret to avoid further discussion in the press but were announced in a press release on the day following the Assembly's opening session on Tuesday August 15th.

The press around the world immediately picked up on the story - Pluto was saved! The committee's proposal was that the solar system would not loose one planet, but gain three - making 12! They decided to let nature determine what determined a planet: as long as it orbited the Sun rather than a planet (so eliminating satellites such as Titan) and was sufficiently large so that gravity made it approximately round, it would be a planet.

This meant that Pluto remained a planet but would be joined by Ceres and Xena. Owen Gingerich, one of the committee, proposed that Mercury, Venus, Earth, Mars, Jupiter, Saturn Uranus and Neptune would be the eight 'classical planets', while Pluto, Ceres and Xena would become known as 'dwarf planets'.

But if you add Ceres and Xena to the original nine you get eleven, not 12! What could be the other' In what was probably the biggest surprise as a result of the proposal, Charon, the 'satellite' of Pluto was also elevated to the status of a planet. But why Charon' Charon is about 1/7th the mass of Pluto and thus their common centre of gravity is about 1/7th the distance from the centre of Pluto towards Charon - well outside its radius. The committee thus decided that the Pluto and Charon system should be classed as a 'binary planet' rather than as a planet and satellite. If so, it is entirely logical that Charon should itself be given the status of a planet. Jim Christy, the discoverer of Charon, was astounded to find that he would join the exclusive list of planetary discoverers! The New Horizons space probe team were also delighted, their craft would now be visiting two planets, not one.

The major problem with this proposal was that it would allow more and more objects to become 'planets' - 12 were already waiting in the wings (or rather the Kuiper belt) and, given time, it was calculated that the Sun could have as many as 100 planets! One problem was the 'roundness' part of the definition. A rocky object (formed of a relatively strong material) needs to be about 700 km across to become round, but the 'ice dwarfs' would only need to be around 400 km in diameter.

Many astronomers were not happy with the proposal and saw it as an artificial way to keep Pluto's status as a planet. They felt that the criteria should not just consider an object's physical properties but should also include aspects of their environment. Just because Ceres is round should not give it a different status from the thousands of other asteroids that orbit the Sun in a swarm between Mars and Jupiter.

By Friday the 18th of August a rebellion against the twelve-planet proposal was beginning to arise. Twenty astronomers put forward a counter proposal that defined a planet as being "by far the largest object in its local population". This may have been a rather clumsy definition, but the idea was clear - because of their gravity, the eight classical planets dominate their orbital neighbourhood. Small spherical bodies such as Ceres and Pluto could be called 'dwarf planets' but there would be only eight real planets!

On Tuesday, August 22nd, there was major confrontation with the rebels who demanded that the dynamical considerations must be included in the definition of a planet and the text of the resolution was again re-written to make a distinction between planets - spherical objects orbiting the Sun which were the largest in their local population zone - and others to be called dwarf planets for which the first two, but not the third criteria applied. The part "the largest in their local population zone" was not liked and, in the resolution that was presented to the IAU two days later, this had been changed to "has cleared the neighbourhood around its orbit."

On the final day of the assembly the IAU astronomers found that they had four proposals to vote on. Most of the participants had left by then, only 400 (of ~ 2000) were there to consider the resolution. All those in the hall had yellow cards to hold up to record their vote and students were present to count them if a majority was not obvious

The first resolution - what constituted a planet - was carried with a clear majority. Spherical objects that had not cleared their neighbourhood would be known as dwarf planets and all other objects, such as asteroids and comets, would be termed "small solar system objects".

The second resolution was an amendment to the first to add the word "classical" to planets which would enable Pluto to remain a nominal planet, but this was rejected by an overwhelming majority - no longer was Pluto classed as a planet. A further resolution did, at least, give it some status as the prototype of a new class of objects; that of tran-Neptunian ice dwarfs in hydrostatic equilibrium - those with periods longer than 200 years - to be named "Plutoids".

The author was eligible to vote, but was at another conference at the time so not present. Whilst totally agreeing with the result - if Pluto were to be discovered today it would never be given the status of a planet - he feels a little sad at its demise. It has become part of our culture and will be missed!

Promotion for Pluto - at least in New Mexico

On March 13th 2007, 77 years after Pluto's discovery, the 70 members of the New Mexico House of Representatives unanimously voted to restore Pluto's status as a full planet. Clyde Tombaugh's widow, Patsy, and their daughter, Annette, were in the public gallery and were obviously delighted!

A formal name for Xena

A petition, signed by over 300 hundred astronomers, was presented to the IAU asking that a better planetary definition be produced that would the be voted on at the IAU General Assembly in Rio de Janeiro in August 2009. This did not come to pass. Interestingly, Mike Brown, the discoverer of 2003 UB303, "Xena", did not sign the petition. Though he accepted that the wording of the 2006 resolution left something to be desired, and much as he would have liked to join the very few who had discovered a planet, he accepted that the right decision had been made. Now, its status determined, a formal name for Xena had to be given and Brown proposed the name Eris, the Greek goddess of discord and strife. A better name could hardly have been given considering that it had caused what was one of the bitterest disputes in the history of astronomy! Xena's satellite, which had been originally called Gabrielle, needed a formal name as well and was named Dysnomia, appropriately so as she was Eris's daughter and the demon of lawlessness.

Pluto and Eris were then given their numbers in the list of minor planets, 134,340 for Pluto and 136,199 for Eris. The author finds this rather demeaning as the minor planet named after Venetia Burney is no 6,235 and even that named after him is number 15,727! The objects that surround them in the list of minor planets are only a few km across - surely this cannot be right. It occurred to the author that something could perhaps be done about this and has proposed a resolution for the IAU to consider that dwarf planets should not be included within the list of minor planets but should, instead, be given their own listings within a new category of "dwarf planets". In the, perhaps unlikely, event that this were adopted at the 2012 IAU General Assembly in Bejing, then Ceres would become DP 01, Pluto DP 02 and Eris DP 03.

How many dwarf planets?

So far, only Ceres and Pluto have been observed in sufficient detail to prove that they fit the definition of a dwarf planet, but as Eris is more massive than Pluto it is almost certain to be spherical and so is accepted as one by the IAU. Since 2006, the IAU has decided that trans-Neptunian objects with an absolute magnitude less than +1 (and hence, assuming that they were perfectly reflecting, must have a minimum diameter of 838 km) are to be named under the assumption that they are dwarf planets. At present (October 2009) two other bodies have met this criteria, and have been classified as dwarf planets, with the names Makemake and Haumea.

Astronomers suspect that at least another 40 known objects in the Solar System are dwarf planets, and estimate that up to 200 dwarf planets may be found when the entire Kuiper belt region is explored. (Currently, Pluto, Haumea, and Makemake are Kuiper belt dwarf planets.) If objects, such as Eris, that have been scattered by interactions with the outer planets to the far reaches of the solar system beyond the Kuiper belt are considered, the number might be as high as 2,000!

There are many discoveries that have yet to be made - but now, of course, Planet X can never be discovered!