

Beyond Mnemonics: Pluto and the Nature of Science

by

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Introduction

If your students were upset following the August 24th announcement from the International Astronomical Union that Pluto was demoted from its standing among the now eight major planets to a new category of “dwarf planet”, you are not alone. Students, many of whom were taught the order of the planets using variations of the common mnemonic “My Very Educated Mother Just Served Us Nine Pizzas”, now express confusion and dismay at the loss of Pluto. The confusion is understandable. After all, if students are taught that the solar system has nine planets as a fact, how can that change? Although going from nine to eight planets can be both confusing and disturbing, it is also an excellent opportunity to discuss the nature of science. The National Science Education Standards “rest on the premise that science is an active process” (NRC, 1996), and the Pluto debate reflects this view. All too often science is perceived to be (and taught as) a collection of facts. In a statement released in 2000, the American Astronomical Society described science, “not [as] a collection of facts but an ongoing process, with continual revisions and refinements of concepts necessary in order to arrive at the best current views of the Universe.”

Knowing something about how and why the decision to demote Pluto was made is important for students of science - and interested members of the general public - to understand. The International Astronomical Union (IAU) is an organization composed of nearly 9,000 astronomers from all over the world, and is only body with the authority and responsibility to assign designations to astronomical bodies and their surface features. The IAU’s ruling on the status of Pluto is in line with the dynamic nature of science and the proposals and debate that preceded the ruling are excellent examples of science as a human endeavor. A bit of background in the history of planet discoveries in the past few centuries and recent strides in understanding the nature of our solar system would be useful in order to understand both the ruling on Pluto’s status and the scientific controversy preceding and accompanying the refined definition of “planet”.

The History of Pluto

Only six planets in our solar system, including Earth, are visible without the aid of a telescope. When Uranus was discovered in 1781, astronomers noticed that some unknown object appeared to be affecting its orbit. The search for this unknown world led to the discovery of Neptune in 1846. Estimates of Neptune’s mass, however, did not seem sufficient to explain the orbital irregularities of Uranus (Hoyt, 1980). Neptune’s orbit, too, was slightly different than calculations predicted. Many astronomers, including Percival Lowell, the astronomer famous for sketching canals on Mars and founder of the Lowell Observatory in Flagstaff, Arizona, believed that the apparent irregularities in the calculated orbits of Uranus and

Neptune could be explained by yet another large planet in the outer solar system. The hunt for Planet X seemed successful when, on February 18, 1930, a young astronomer named Clyde Tombaugh discovered a faint object moving against the fixed background stars on photographic plates he had taken as part of a sky survey he was hired to conduct at Lowell Observatory. The newly discovered object was given the name Pluto, after the Roman god of the underworld. (An 11 year-old girl Venetia Burney in Oxford England first suggested the name Pluto.) For more than 45 years, Pluto’s strangely elliptical orbit and the light reflected by the newly discovered object was all that was known about this distant world.

Determining the size of Pluto directly through observations proved difficult for most of the 20th century with even the best telescopes. Indirect calculations of Pluto’s diameter from its known brightness required assumptions of its reflectivity (a property known to planetary scientists as albedo.) If Pluto had a very low albedo, similar to the Moon’s average value of 11%, it could be the size of Mars. A Mars-diameter object would be roughly consistent with measurements of Pluto’s diameter by Gerald Kuiper in 1950 (Marcialis and Merline 1998). In 1976, astronomers using a reflectivity of 40% (a moderate value similar to that of both Earth and Neptune) calculated the diameter of Pluto to be 3300 km, which is close to the diameter of the Moon. In 1978, James Christy discovered Pluto’s large moon, Charon. Careful observations of the orbit of the satellite allowed Pluto’s mass to be calculated using Kepler’s third law, and showed it to be about 1/5th of the mass of our Moon. In the mid 1980s the orbital plane of Charon was such that Charon crossed directly in front of (a transit) and behind Pluto (an occultation), resulting in a series of mutual eclipses as viewed from the Earth. Astronomers observing Charon pass before and behind Pluto were able to accurately determine the radii of the two worlds. Pluto was also found to have a relatively high average reflectivity of ~50%, consistent with a small size (Young and Benzel, 1994). Rather than being the giant planet predicted to be responsible for the perturbations in the orbits of Uranus and Neptune, Pluto is just 2/3 the diameter of the Moon and the Pluto-Charon system totals a mere 0.22% of the Earth’s mass. Pluto could not be the object predicted to be disturbing the orbits of the Uranus and Neptune. So what about Planet X? By 1989, Voyager 2 had flown by all four giant planets and had accurately measured their masses. New calculations based on Voyager 2’s data did not show the orbital perturbations that led Percival Lowell and many of his contemporaries to hypothesize the existence of Planet X (Standish, 1993). Pluto’s discovery had been based on a faulty prediction – and the careful search of Clyde Tombaugh.

One in a Large Family

Many astronomers argue that if Pluto were discovered

today it would simply be classified as a large member of a class of recently discovered solar system bodies called Kuiper Belt Objects (KBOs). However, as long as Pluto remained the largest object with an orbit taking it beyond Neptune, it seemed safe. Then in 2003 Michael Brown of CalTech announced that he had discovered an object called UB 313 (nicknamed Xena) in an area of the solar system beyond the orbit of Neptune called the Kuiper Belt.

The existence of the Kuiper Belt has been known since 1992 (Jewitt and Luu, 1993), but was hypothesized by astronomers in the mid-20th century who were trying to identify the sources of comets. Comets, which are debris left over from the formation of the solar system fall into two general categories: long-period comets (orbital periods greater than >200 km) which come from all directions in the sky, and short period comets (orbital periods of < 200 km) which typically have orbits relatively close to the plane of planetary orbits and in the same direction as the orbits of the planets.

In 1950 Jan Oort proposed the idea of the Oort cloud, a cometary reservoir for long-period comets extending at least 1/3 of the way to the nearest star to our solar system. In 1951, Gerald Kuiper proposed a closer reservoir for the short period comets, which was similar to an idea by proposed several years previously by Kenneth Edgeworth (Jewitt, 1999). This band of icy objects, commonly known as the Kuiper Belt, have orbits that lie roughly in the plane of the solar system. So where did the two populations come from? According to leading models of planetary formation, when the giant planets were forming untold numbers of small icy bodies were deflected out of giant planets' formation zones (Weissman, 1999). Some of these bodies were sent into orbits at the edge of the Sun's gravitational influence, primarily by Jupiter and Saturn, and became the Oort cloud. Neptune and Uranus tended to deflect small bodies in their formation zones toward Jupiter, which would then scatter them in all directions, but most often away from the Sun. During this process small objects that never came together to form a larger planet were cleared out from inner edge of the Kuiper Belt. A few of the larger members of this group remained in the area of Neptune's orbit. In an unlikely event, Triton was captured as a moon of Neptune. The Pluto-Charon system, UB 313, and smaller Kuiper Belt Objects (KBOs) were spared because they never come close to Neptune. Pluto, and many other KBOs, orbit in what is known as a 3:2 resonance (Jewitt, 1999). For every three orbits Neptune completes, Pluto completes two, and the two worlds never come closer than about 17 times the Earth-Sun distance (Malhorta, 1999) despite the fact that the Pluto crosses the orbit of Neptune.

Beyond Pluto astronomers expect that there are many more KBOs, some of which lie in orbits that were never disturbed by Neptune. More than 1000 KBOs have been found to date (NASA, 2006). More distant objects with disturbed orbits, like the 1800 km object Sedna (Brown *et al.*, 2004) are also waiting to be discovered beyond the Kuiper Belt. Thanks to the hard work of astronomers in the past 14 years, we now know that Pluto is a sizable member of the Kuiper Belt, a region believed to be populated with on the order of 100,000 icy bodies objects with diameters of >100 km (detectable from Earth), and as

many as 10 billion smaller objects (Stern, 2003). Although the numbers are large, even the largest objects are tiny compared to the Earth; the combined mass of the Kuiper Belt is predicted to be significantly less than that of our planet.

Reasoning and Controversy

The debate on Pluto's status reached a new level and urgency after the 2005 announcement that UB 313 is larger than Pluto (Brown *et al.*, 2005), but astronomers had been publicly wrestling with the issue since 1998. Six years after the discovery of the first KBO, some members of the IAU suggested Pluto be reduced from major planet to minor planet status – a classification also given to asteroids and comets. In 1998 only relatively small KBOs had been discovered, and the IAU firmly supported planet status for Pluto (IAU, 1999). But once the diameter of UB 313 was announced in 2005 a decision had to be made. Does the solar system have 8 planets, or 10, 11, or more? When Ceres was demoted from planet status (see Hairston, 2006), an important piece of information crucial to the current discussion was missing – an observation of its “roundness”. With a diameter of about 950 km Ceres is the largest member of the asteroid belt, and has at least one important difference when compared with all other asteroids. In 2005, the Hubble Space Telescope confirmed that Ceres has enough mass for gravity to pull the rocky object into a spherical – or round – shape. Saturn's icy moon Mima is round with a diameter of just under 400 km, and has significantly less mass than Ceres, simply because ice isn't as strong rock and is more easily pulled into a spherical shape. Relatively small KBOs with diameters >400 km should be round, too. Less than two weeks before the decision to reclassify Pluto, a proposal seriously considered by the IAU would have conveyed planet status on three other objects: Ceres, UB 313, and Charon, which orbits a point just outside of Pluto (the center of mass of the Pluto-Charon system). The suggestion was similar to one supported by several leading planetary astronomers that would convey planet status upon any naturally occurring “round” object that orbits the Sun and not another planet. This definition would have the advantage of being based on a physical property – a planet in our solar system would be an object orbiting the Sun that has sufficient mass for its own gravity to overcome the material strength of the material of which it was composed, whether that be rock or an icy-rock mixture. The proposed IAU definition would have classified any round object larger than 800 km in diameter that orbits the sun and has a mass roughly 1/12,000 of Earth's mass (an object large enough to be spherical due to its own gravity if made of rock).

The with problem broadening the category of planet, as pointed out by Mike Brown, the discover of UB 313, is that the solar system would soon have many more planets as ongoing surveys of the Kuiper Belt uncover more objects fitting the roundness criteria (Brown, 2006). If dropping one planet from the solar system is confusing, imagine adding dozens, a 100, or even more new planets to the family. If the simple roundness criteria had been applied, we would have 53 planets as of the present day (Brown, 2006). Had the IAU's proposal of mid August 2006 been adopted, we would have 12 planets today,

but many more tomorrow. The mid-August proposal was met by an outcry from the astronomical community, including members of IAU. On August 24, 2006 the IAU adopted a different strategy when it officially stated that a planet:

- (a) is in orbit around the Sun,
- (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and
- (c) has cleared the neighborhood around its orbit.

By the third criteria, Pluto is no longer a planet, but instead is reclassified as a dwarf planet, along with other solar system bodies satisfying only the first two criteria. All other naturally occurring objects satisfying the first criteria (e.g. not moons) will be officially known as small solar system bodies rather than minor planets. Essentially the new three-tiered classification is a compromise. The new class of dwarf planet allows for the roundness criteria to be applied while allowing the classification of planet to be reserved for the eight larger, familiar solar system objects. These dwarf planets can also be thought of as planetary embryos: objects that due to their small combined mass, or the dynamical influence of a much more

massive neighbor, never managed to merge to form a larger body that would fall under the new category of planet.

The decision of the IAU was made only by members present in Prague, was not unanimous, and certainly did not please everyone in the astronomical community. For many astronomers, the new IAU definition lacks the elegant simplicity of the roundness proposal. By the time of this writing, one week after the decision, protests by professional astronomers have already begun. However, unless the IAU reverses its decision in the future, our solar system will continue to have 8 planets. In addition it will have a growing number of objects classified as dwarf planets, a plethora of irregularly shaped small solar system bodies, as well as numerous moons, both large and

UT Dallas Professor Mary Urquhart stands in front of a scale model depicting the relative sizes of Jupiter (27.5 cm), Earth (2.5 cm), and Pluto (.44 cm) compared with the Sun (274 cm) at Boon Elementary in Allen ISD. With an actual diameter of 2,274 km (less than 1/5th the diameter of the Earth), the real Pluto is significantly smaller than the eight objects now classified by the International Astronomical Union as planets.



round, and small and irregular. Children, educators, and textbook publishers will not be charged with the task of keeping up with a very large – and growing – planetary family. The category of dwarf planets provides a scientifically reasonable, if not entirely satisfying, way of classifying objects that meet the roundness criteria but are significantly smaller than all of the 8 planets. Our understanding of the solar system will also continue to change, but in a manageable way. Dwarf planets, small solar system bodies, and small moons will continue to be discovered, as were Pluto’s tiny moons (Space Telescope Science Institute, 2006), named Hydra and Nix by the IAU. (Moons don’t make a planet. Even small solar system bodies can have moons, such as the 58 km long asteroid Ida and its 1.6 km long moon Dactyl.)

Pluto and the Classroom

So how do you discuss the status of Pluto with those upset elementary and middle school students required to learn the components of the solar system? Perhaps just by explaining that:

- Astronomers originally called Pluto a planet because they thought it was much bigger than it actually is. Finding answers in science takes time, and our ideas change when we get new data.
- Astronomers now know that Pluto is a large, but not the largest, member of a group of objects in the cold outer solar system known as the Kuiper Belt. The Kuiper Belt is where many comets come from, and Pluto is like a very big comet that stays far from the Sun.
- Pluto, the asteroid Ceres, and the new object that is bigger than Pluto (UB 313) are all now called dwarf planets. Astronomers expect to find many more dwarf planets in the Kuiper Belt.
- Pluto is still important to scientists. NASA launched a spacecraft called New Horizons that will visit Pluto and other members of its family last January. Because Pluto is so far away, it will take about 10 years for spacecraft to get to Pluto.

Our efforts to help children learn the names and order of the planets may be part of the source of their outcry over Pluto’s change in status. Knowledge is important, but does simply memorizing My Very Educated Mother Served Us Nine Pizzas (or Nachos) really help children understand the solar system in which we live? Behind the changes in the definition of “planet”, and the mnemonics sure to follow, is something much more important and at the core of the scientific process – a change in *understanding*. New discoveries lead to changing understanding of the nature of the universe, but often in the process there is much debate and disagreement in the scientific community before a consensus is reached. Rather than being a source of dismay for children and their teachers, public debates, such as that surrounding how astronomers should classify Pluto, are an opportunity. These exchanges expose us all to the dynamic nature of science and how scientists, as human beings, struggle to develop consensus in response to important new

world-view-changing data. The debate over Pluto highlights just how rich the scientific understanding of the solar system has become, and how much more there is yet to learn. By the time the NASA spacecraft New Horizons reaches Pluto and begins its exploration of the Kuiper Belt, today’s 3rd graders learning the order of the planets will be preparing to enter their freshman year of college. Pluto, Charon, UB 313, and the 41 other large Kuiper Belt objects will undoubtedly be recognized as part of a much larger known family. And dwarf planet or one of the nine familiar to schoolchildren, Pluto will still be Pluto. The universe hasn’t changed; only our understanding of it has. That, too, is the nature of science.

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