Why Pluto Matters

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The one thing most people know about the planets is that My Very Educated Mother Just Served Us Nine Pizzas[1]. This is a mnemonic device taught to students to help them remember the number and order of the planets – Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto. According to the International Astronomical Union (IAU) however, the word ‘pizzas’ will now have to be removed from this saying.

In August 2006, a group around 400 astronomers meeting in Prague decided that our solar system now has eight planets instead of nine. This decision has caused a lot of controversy both inside and outside of the scientific community. There are many astronomers who are upset by Pluto’s removal from the list of planets, but school children, astrologers[2], politicians[3] and the family of the man who discovered Pluto[4] are upset as well.

Even though the IAU has made its decision about Pluto, astronomers still do not agree about how many planets there are in our solar system. If you asked an astronomer this question, you could be told that there are 8, 9, 10, 12 or more than a dozen, depending on

[1] Or maybe they would say Mother Very Earnestly Made Jam Sandwiches Using No Peanuts.
[2] Pluto's demotion divides astrologers, troubles Scorpios (August 25, 2006) http://www.moneyweb.co.za/shares/international_news/960647.htm
[3] California House Resolution No. 36 (August 24, 2006) http://www.leginfo.ca.gov/pub/bill/asm/ab_0001-0050/hr_36_bill_20060824_introduced.pdf
[4] Clyde Tombaugh's Family Joins Protest of Pluto's Downgrade (September 5, 2006) http://space.com/news/060905_pluto_protest.html

who you talked to.

It is reasonable to assume that new planets could be discovered as the magnifying power of telescopes improves, but how is it possible to lose a planet or to lose track of how many planets there are? How is it decided what will qualify as a planet and what won't? Why would changing the status of a planet upset so many people? This paper seeks to answer each of these questions.

This paper will look at the current controversy surrounding Pluto to determine how the reclassification process works and what forces have shaped the selection of a new system. In the paper I will follow the definitions in Geoffrey Bowker and Susan Leigh Star's book *To Classify Is Human.* A classification is defined as a spatial, temporal, or spatio-temporal segmentation of the world and a classification system is a set of boxes (metaphorical or literal) into which things can be put to then do some kind of work[5]. According to this definition of a classification system, a definition for a planet is not needed as long as there is agreement in the community about which object belongs in which box.

This paper will also look at the history of planetary classification systems to determine how planets have been defined in practice over time. Four distinct periods will be reviewed (the dates below are an attempt to mark the beginning of controversy associated with each shift of systems):

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[5] Bowker, Geoffrey C. and Susan Leigh Star, "To Classify is Human," page 10 in Sorting Things Out: Classification and Its Consequences. MIT Press, 1999.

- A static Earth-centered planetary system with 7 planets
  (Approx. 150 AD to 1543)
- A static Sun-centered planetary system with 6 planets
  (1543 to 1781)
- A dynamic Sun-centered planetary system with a varying number of planets that settled at 9
  (1781 to 1990s)
- A dynamic set of planetary systems centered around multiple stars with both the total number of planets and the number of planets in our local solar system in dispute
  (Today)

It is impossible to clearly define when one classification system was in use and when another took over. These systems are mutually exclusive, but in periods of transition multiple systems have been in use at once. As we are seeing today, there was not a wholesale switch in usage the day after the IAU made their decision about Pluto's status. If this decision does reach widespread acceptance, it will take years to change textbooks, update museum displays and replace all references to Pluto's previous planetary status.

The transitions between classification systems can be viewed as paradigm shifts[6] as defined by Thomas Kuhn in *The Structure of Scientific Revolutions*. In fact, Kuhn used the transition from the dominant Earth-centered cosmology to Copernicus' Sun-centered

[6] In brief, his theory states that a scientific revolution occurs when scientists encounter anomalies which cannot be explained by the current universally accepted paradigm. When enough significant anomalies have accrued against a current paradigm, the scientific discipline is thrown into a state of crisis. During this crisis, new ideas, perhaps ones previously discarded, are tried. Eventually a new paradigm is formed, which gains its own new followers, and an intellectual "battle" takes place between the followers of the new paradigm and the hold-outs of the old paradigm. (http://en.wikipedia.org/wiki/Paradigm_shift)

cosmology as a key example in his theory. This paper will show that the astronomy community in 2006 in the middle of a crisis that is provoking a change from one paradigm to another.

Although the introduction of new technology closely parallels these shifts in planetary classification systems, the new technologies have served more as catalysts that provoke a crisis in astronomy than as experimental tools that provide scientific data to resolve a crisis. Astronomers have moved from making observations using the naked eye, to small hand-made telescopes, to million-dollar observatories and most recently to hundred-million-dollar space probes, but none of these tools can be used to determine what will be counted as a planet and what won't be.

This paper will also look at the how this debate may be resolved by using the concept of closure mechanisms found in H.M. Collins' book *Changing Order: Replication and Induction in Scientific Practice*. More interesting than seeing how this debate might be brought to a conclusion though, is comparing Collins' closure mechanisms with the process that many in the scientific community think should be used to end the debate. For most, the scientific method provides the definition for how science is carried out, even if "hardly anyone has extended experience of what it is like to produce new scientific knowledge out of a controversial area[7]." Instead of using this process, Collins states that members of a scientific community negotiate their way to a consensus using both scientific and non-scientific arguments to win the rest of the group over to their side of the controversy.

[7] Collins, H.M., "Changing Order: Replication and Induction in Scientific Practice," page 144, The University of Chicago Press, 1992

The Current Controversy

The IAU is an organization made up of professional astronomers from around the world and it serves as the authority for assigning designations to celestial bodies and any surface features on them. The organization was founded in 1919 and the organization's main office is located at the Institut d'Astrophysique in Paris, France[8].

Every three years the IAU holds a General Assembly where members are able to vote on various resolutions. Most resolutions, such as IAU 2006 Resolution 3: Re-definition of Barycentric Dynamical Time[9], are technical and don't receive any attention outside of the astronomy community. At the XXVIth General Assembly held from August 14-25, 2006, Resolutions 5 and 6 generated a controversy that was covered in major media outlets around the world.

The IAU was trying to come up with a formal definition for the word planet, something that hadn't existed before. "It's something of an embarrassment that we have no definition of what a planet is," Professor Basri, an astronomer at the University of California, was quoted as saying in 2003 in the *Berkeley News*. "People like to classify things. We live on a planet; it would be nice to know what that was.[10]"

Recent discoveries have forced the astronomy community to confront the issue of how

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[8] http://www.iau.org/Welcome.249.0.html
[9] http://www.iau.org/Resolutions_at_GA-XXVI.340.0.html
[10] Pluto may lose planet status (March 10, 2003)
http://www.smh.com.au/articles/2003/03/09/1047144868646.html

planets are classified. The Hubble Space Telescope was launched in 1990 and has since made many ground-breaking observations. Advances in computer technology during the 1990s also made traditional observatories more powerful, most notably through the use of adaptive optics[11]. With these new tools, astronomers started to discover objects not just beyond Pluto's orbit but objects circling stars in other solar systems.

Hundreds of objects have been found that orbit the Sun at a distance greater than Neptune[12]. These objects have been variously called Trans-Neptunian objects (TNOs), Kuiper belt objects (KBOs), scattered disk objects (SDOs), cubewanos and mesoplanets. Over 800 of these objects have been found and many of them are of significant size[13]. 50000 Quaoar, discovered in 2002, is half the size of Pluto and is larger than the largest asteroid. 90377 Sedna, discovered in 2003, is estimated to be as large as two-thirds of Pluto. 136199 Eris[14], discovered in 2005, has been observed to be slightly larger than Pluto but exact measurements are difficult to make[15].

As long as the new objects being found were smaller than Pluto it was easy to classify them as something other than a planet, but the discovery of Eris in 2005 meant that the issue could not be put off any more. At the time of the discovery, some people started referring to this object as the 10th planet and others wanted to classify it as just another KBO. Since Pluto had been used informally as the threshold for the minimum size of a

[11] http://en.wikipedia.org/wiki/Adaptive_optics

[12] Although Pluto is listed in the order of planets after Neptune, its orbit sometimes crosses Neptune's and during this part of the orbit Neptune is then the most distant known planet. Because of this, these new objects are measured as being beyond Neptune's orbit instead of Pluto's orbit.

[13] The Minor Planet Center maintains a current list of Trans-Neptunian Objects at http://cfa-www.harvard.edu/iau/lists/TNOs.html

[14] This object has also been referred to as 2003 UB_{313} and Xena.

[15] Planet Discovered Last Year, Thought to Be Larger Than Pluto, Proves Roughly the Same Size (April 12, 2006) http://www.nytimes.com/2006/04/12/science/space/12planet.html

planet, the status of Eris depended on the status of Pluto. If Pluto was a planet, then how could this new larger object not be? If Pluto was now a KBO and was no longer the cutoff point for classifying planets, what else would be used to determine a new object's status?

The IAU chose to define a planet as an object that is in orbit around the Sun, has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and has cleared the neighborhood around its orbit[16]. Even with this new definition, the difference between a planet and an object that is not a planet is not clear cut though.

One common argument against the definition is that it doesn't state how round on object needs to be. For instance, the Earth bulges along the equator and is not a perfect sphere. The definition also doesn't state how clear the neighborhood around an object needs to be. For instance, there are a large number of asteroids that share the orbit of Jupiter[17]. So to some degree the previous minimum size threshold has been replaced with two new thresholds that leave room for ambiguity[18].

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[16] Resolution 5: Definition of a Planet in the Solar System http://www.iau.org/Resolutions_5-6.398.0.html

[17] http://en.wikipedia.org/wiki/Trojan_asteroids

[18] There is an additional issue of distinguishing between a planet and a star that is being raised by the discovery a very large extrasolar planets that this definition of a planet does not clarify. Because of the sensitivity of current detection methods, all of the objects that have been found orbiting other stars are relatively large and range in size from many times the mass of Jupiter to approximately five-and-a-half times the mass of Earth. Brown dwarfs are classified as stars that are not massive enough to sustain hydrogen fusion that range from approximately 5 to 90 Jupiter masses. Many of the objects that have been discovered are within this size range and several are estimated to have masses of at least 11 Jupiters. These objects have been classified as extrasolar planets when found orbiting a star and this makes them both stars and planets according to overlapping classification systems. The IAU has acknowledged this issue by explicitly stating that their new definition only applies to planets in our solar system. A definition of planets that is general enough to apply to objects orbiting any star is not currently available.

These were not the only possible criteria that could have been used to determine an object's status. Composition could have been used to distinguish between objects. The first 8 planets are divided into two groups -- the first 4 planets, Mercury, Venus, Earth and Mars are made of metal and rock while the next 4 planets, Jupiter, Saturn, Uranus and Neptune are made of gas. Some astronomers say that we are only now beginning to find a third class of icy planets and that Pluto, Sedna, and other large TNOs are the first of the new planets that we have found.

Orbits could also have been used as a determinant. The first 8 planets are found very close to the ecliptic and have orbits with small eccentricities. Pluto's orbit is tilted about 17° from the ecliptic[19] and has an extremely eccentric orbit that takes it within the orbit of Neptune for about 20 years of its 249 year orbit. A threshold could have been set for a planetary orbit's acceptable degree of inclination or eccentricity.

None of these characteristics provide an objective test for an object's planet-ness however. This poses a problem, since Bowker and Star in their book *To Classify Is Human* say that an ideal classification system is a complete system that uses mutually exclusive categories that are based on consistent, unique principles. If this is so, how can the IAU ever decide how many planets there are and how to classify new discoveries? Bowker and Star offer the following solution:

> No real-world working classification system that we have looked at

[19] For comparison, Mercury has an orbital inclination of 7°.

> meets these “simple” requirements and we doubt that any ever could. In the case of unique classificatory systems, people disagree about their nature; they ignore or misunderstand them; or they routinely mix together different and contradictory principles. [...] Mutual exclusivity may be impossible in practice, as when there is a disagreement or ambivalence about the membership of an object in a category[20].

Bowker and Star broadly define classification as an agreed upon naming scheme that need not follow any classificatory principle. Although categories may become objects of contention, they do serve a function of allowing people to communicate information to each other, even if those people do not believe in the categories they are using. In this sense, planets are simply what astronomers working with the data of astronomy choose to call a planet.

The Not So Fixed Stars

It has been over 70 years since a new object has been added to the list of planets. Before Pluto was removed, it had been over a hundred years since another planet was taken off of the list. Because these events happen so infrequently, it is easy to forget how often the number and order of the planets have changed over time. This section provides a brief history of planetary classification systems in order to put today’s controversy over Pluto in context.

[20] Bowker, Geoffrey C. and Susan Leigh Star, "To Classify is Human," pages 11-12 in Sorting Things Out: Classification and Its Consequences. MIT Press, 1999.

The word ‘planet’ is derived from Greek and means wanderer. Before telescopes were invented, planets were identified by how they moved in the night sky. To the naked eye both planets and stars appear as points of light, but people who observe the sky throughout the year will notice that they move in different ways. For example, a star in the constellation Orion will always appear in the same relative position to the other stars and all stars move regularly in the same direction. Planets on the other hand move in one direction and then sometimes appear to stop and then move backward for a short period before moving forward again. This phenomenon is called retrograde motion[21].

This motion allowed people to classify planets as celestial objects that were wandering from the path that the stars were following. In this classification system there were 7 planets – the Moon, Mercury, Venus, the Sun, Mars, Jupiter and Saturn. This list includes some objects we don't consider to be planets today and is missing 4 objects that we have thought of as planets. In this system, the Sun and the Moon were part of the list because they were objects in the sky that wandered from the path of the stars. Uranus, Neptune and Pluto weren't included because they couldn’t be distinguished from the stars with the naked eye and the Earth was not included because it was not identified as a celestial object.

This particular Earth-centered cosmology was not the only one developed before the invention of the telescope, but it did become the dominant paradigm, at least in the Greek and Roman world. A complete history of planetary classification systems would look at astronomy in other ancient cultures. For instance, the Maya had developed a

[21] http://www.opencourse.info/astronomy/introduction/05.motion_planets/

sophisticated cosmology that allowed them to predict when eclipses occur, when Venus appears as a morning star and when Mars goes into retrograde motion[22]. There were also Sun-centered planetary systems proposed by ancient Greek astronomers.

Claudius Ptolemaeus, best known today as Ptolemy, was a Greek living in the 2nd century AD who helped make the Earth-centered classification system the dominant paradigm. His *Almagest* was a compilation of astronomical knowledge and theories that served as the key text of astronomy for over a thousand years. This text taught that the universe was bounded by a fixed sphere of stars that slowly rotated around the Earth and the planets were objects moving in the space between the Earth and the sphere of stars.

The *Almagest* also taught that the structure of the heavens was static. The stars and planets were fixed in number and in position, so any changes that were observed in the sky were interpreted as happening in the upper atmosphere of Earth. Observations of comets, asteroids, the Northern Lights and the Milky Way were made by astronomers of the time, but these were believed to be phenomena that were occurring in the space between the Earth and the Moon. This sublunary sphere contained the mutable elements of earth, wind, air and fire while everything beyond was made of ether, a substance that is permanent, regular, and unchanging.

In 1543, Nicolaus Copernicus published *De revolutionibus orbium coelestium,* a book claiming that the Sun was the center of the universe, not the Earth. In *The Copernican Revolution*, Thomas Kuhn describes the transition to this new theory as "a revolution in

[22] http://ircamera.as.arizona.edu/NatSci102/NatSci102/text/extmayaastronomy.htm

ideas, a transformation in man's conception of the universe and of his own relation to it. Again and again this episode in the history of the Renaissance thought has been proclaimed an epochal turning point in the intellectual development of Western man.[23]"

It was more than a hundred years after the printing of Copernicus' book that the crisis over his heliocentric theory ended. The switch of the Sun and the Earth had enormous social consequences and this created a long and bitter fight over the theory. The Catholic and Protestant churches were the main opponents because it removed the Earth from the privileged position in the center of the universe:

> Copernicanism was potentially destructive of an entire fabric of thought. […] More than a picture of the universe and more than a few lines of Scripture were at stake. The drama of Christian life and the morality that had been made dependent upon it would not readily adapt to a universe in which the earth was just one of a number of planets. Cosmology, morality, and theology had long been interwoven in the traditional fabric of Christian thought described by Dante at the beginning of the fourteenth century. The vigor and venom displayed at the height of the Copernican controversy three centuries later, testifies to the strength and vitality of the tradition[24].

Copernicus' heliocentric theory fundamentally changed how planets were classified. A planet went from being an object that revolved around the Earth that was not a star to

[23] Kuhn, Thomas S., "The Copernican Revolution," p. 1, Harvard University Press, 1997
[24] Kuhn, Thomas S., "The Copernican Revolution," pages 192-193, Harvard University Press, 1997

being an object that revolved around the Sun that was not a star or a satellite. This changed both the number and position of the known planets. In this new system there were 6 planets -- Mercury, Venus, Earth, Mars, Jupiter, and Saturn. The Earth was now a planet, the Moon had become a satellite orbiting the Earth, and the Sun had become the center of the universe.

Technology played a part in the transition by providing data that could not be fit into the existing classification system. The use of the telescope in astronomy showed that not all objects in the universe moved around the Earth. When Galileo looked at the night sky through a small telescope he discovered objects orbiting Jupiter. The Ptolemaic system was unable to deal with this discovery.

New observatories also provided tools that greatly enhanced the precision of naked eye observations. To match predicted values of planetary position to the more accurate observations, the Ptolemaic system had been gradually modified with a series of epicycles, devices that were used to explain retrograde motion. As the system grew and became more unwieldy, astronomers began looking for a more simple solution. The new theory removed the need for epicycles because it showed that since the Earth was a planet that orbited the Sun, it would regularly overtake and pass the outer planets and the inner planets would do the same to the Earth. The planets all moved in a regular motion, but the apparent positions changed as Earth moved about its orbit.

Although the possibility for change in the night sky had been introduced with the discovery of new moons around Jupiter, this classification system just rearranged the known planets and was not able to accommodate the addition of new planets. As the power of telescopes increased, the classification system had to be updated again to account for more new discoveries.

Uranus was the first planet to be discovered that was not known in ancient times. It had been observed on many previous occasions, but was mistakenly identified as a star. Galileo's astronomical drawings show that he had even observed Neptune, but it was also mistaken for a fixed star. Both planets are visible to the naked eye, but since the retrograde motions are too small to notice without the aid of a telescope they were not able to be seen as planets.

Sir William Herschel is given the credit for discovering Uranus in 1781. When he reported his discovery he originally called it a comet[25] and it took time before Uranus was accepted as a new planet. In *The Structure of Scientific Revolutions*, Thomas Kuhn provides some information about this process:

> On at least seventeen different occasions between 1690 and 1781, a number of astronomers, including several of Europe's most eminent observers, had seen a star in positions that we now suppose must have been occupied at the time by Uranus. [...] Herschel, when he first observed the same object twelve years later, did so with a much improved telescope of his own manufacture. As a result, he was able to notice an apparent disk-size that was at least unusual for stars.

[25] http://www.solarsystem.org.uk/uranus/

> Something was awry, and he therefore postponed identification pending further scrutiny. That scrutiny disclosed Uranus' motion among the stars, and Herschel therefore announced that he had seen a new comet! Only several months later, after fruitless attempts to fit the observed motion to a cometary orbit, did Lexell suggest that the orbit was probably planetary. When that suggestion was accepted, there were several fewer stars and one more planet in the world of the professional astronomer. [...] The shift of vision that enabled astronomers to see Uranus, the planet, does not, however, seem to have affected only the perception of that previously observed object. Its consequences were more far-reaching. Probably, though the evidence is equivocal, the minor paradigm change forced by Herschel helped to prepare astronomers for the rapid discovery, after 1801, of the numerous minor planets or asteroids[26].

After this discovery, many new objects were added to the list of planets. Of the new discoveries, today we recognize some of these objects to be planets, some to be asteroids and one to be imaginary.

In 1801, Ceres was discovered between the orbits of Mars and Jupiter and became accepted as a new planet. Ceres soon lost its label as a planet and was reclassified as an asteroid after several other smaller objects were found in a similar orbit. There was a

[26] Kuhn, Thomas S., "The Structure of Scientific Revolutions," pages 115-116, The University of Chicago Press, 1996

short time though when some of these objects were classified as fully fledged planets[27]:

> Note that when Ceres was first discovered in 1801, it was presumed to be a "regular" planet (after it was initially considered as a comet, that is; Uranus had also been thought to be a comet when it was first discovered, because two centuries ago the concept of new "planets" was novel). This presumption held true also for the next three main-belt asteroids (which were found in 1802, 1804, and 1807): they were all considered new planets of the solar system, and were counted as the 8th, 9th, 10th, and 11th planets (or 5th, 6th, 7th, and 8th -- with Jupiter, Saturn, and Uranus moved to the 9th, 10th, and 11th spots). The fifth asteroid was not found until late 1845, and the sixth not until mid-1847, and astronomy textbooks for nearly half a century referred to "eleven primary planets" of the solar system[28].

In 1846, Neptune was discovered after having been predicted to exist based on the mathematical models of Urbain Le Verrier. Astronomers had noticed that Uranus' observed orbit didn't fit with its predicted orbit. Le Verrier proposed that this was due to the gravitational influence of another planet and provided calculations for where the new

[27] Ceres came close to regaining its status as a planet in 2006 when one of the resolutions proposed at the IAU's General Assembly would have defined a planet as a round object orbiting the Sun. This rejected definition would have increased the total number of planets to 12 (adding Ceres, Pluto's moon Charon, and Eris to the list) and would have raised the possibility of adding many more as new discoveries are made. Instead the approved definition created a new category called "dwarf planets" that are spherical objects orbiting the Sun that had not cleared it's orbital neighborhood. Ceres, Pluto and Eris are the first official dwarf planets classified by the IAU. Note that "dwarf planet" is a separate category from minor planet, a term that had been in use to refer to a body that is smaller than a major planet but larger than a meteoroid. As part of their 2006 resolutions, the IAU's created another new category of "Small Solar System Body" to refer to these minor planets.

[28] http://cfa-www.harvard.edu/cfa/ps/icq/ICQPluto.html

object could be found. Shortly after this prediction, Neptune was found very close to the predicted position and was added to the list of planets.

In 1859, Le Verrier also predicted that an anomaly in Mercury's orbit was the cause of an undiscovered planet that he named Vulcan. An amateur astronomer, Edmond Modeste Lescarbault, soon announced that he had observed the planet and many other reported observations followed. In 1915 Mercury's unexpected orbit was explained by Einstein's theory of relativity and the observations of this new planet were discredited. Although Vulcan is no longer considered to be a real object, Richard Baum and William Sheehan in their book *In Search of Planet Vulcan* explain that “To the people of the late 19th century, Vulcan was real. It was a planet. It had theoretical credibility and had actually been seen. Even textbooks accorded it a chapter[29].”

In 1930, Pluto was discovered by Clyde Tombaugh at the Lowell Observatory in Arizona. By that point, the discovery of new planets had become almost routine and there was no dispute about Pluto's status. A moon, Charon, was observed circling Pluto in 1978 and this served to reinforce Pluto's status[30]. Although the classification system of the time had labeled some recently discovered objects as something other than a major planet such as the objects in the asteroid belt, Pluto was considered to be as much of a planet as all of the others.

Sources of Opposition

[29] Baum, Richard and Sheehan, William, "In Search of Planet Vulcan: The Ghost in Newton's Clockwork Universe," p. vii, Basic Books, 2003
[30] Mercury and Venus are the only planets that don't have moons.

This brief history shows that the list of planets has changed repeatedly in the past and there has often been conflict associated with a transition from one classification system to another. Although it is clear that people both inside and outside of the astronomy community are upset about Pluto's demotion at the hands of the IAU, it is not clear why they are upset.

Even though Pluto is seemingly removed from our daily life by over a billion miles, determining Pluto's status has consequences for people on Earth. As Bowker and Star point out, "For any individual, group or situation, classifications and standards give advantage or they give suffering. Jobs are made and lost; some regions benefit at the expense of others[31]."

For people on Earth there are non-scientific factors such as money, career advancement, national prestige, tradition and numerology that are shaping the debate about the definition of a planet. This paper looks at just some of the sources of opposition within the scientific community and does not seek to explain the reasons the general public is upset with the change in Pluto's status.

In January 2006, NASA launched the New Horizons[32] mission to study Pluto. With the launch of New Horizons there was much fanfare about the fact that this mission would "complete the initial reconnaissance of the planets in the solar system.[33]" Alan Stern is

[31] Bowker, Geoffrey C. and Susan Leigh Star, "To Classify is Human," page 6 in Sorting Things Out: Classification and Its Consequences. MIT Press, 1999.
[32] http://www.nasa.gov/mission_pages/newhorizons/main/index.html
[33] http://www.nasa.gov/home/hqnews/2005/dec/HQ_05550_New_Horizons.html

an American scientist and the Principal Investigator of the New Horizons mission. He is also one of about 300 scientists who signed a petition[34] against the IAU's resolution about Pluto and he has stated that "on [the New Horizons] Web site and in documents, discussions and other aspects of the New Horizons mission, we will continue to refer to Pluto as the ninth planet[35]."

In his book *Pluto and Charon*, Alan Stern talks about the difficulties in getting a probe to Pluto built. He was one of the scientists who formed the Pluto Underground in 1989, an informal group of scientists who sought to convince NASA of the importance of exploring Pluto. Part of their case for Pluto was that it was the only planet that had not yet been explored by one of NASA's spacecraft. This provided motivation not just for NASA administrators who would allocate funds for a probe, but to the engineers who wanted to build a probe:

> Back in 1989, [two spacecraft engineers] had seen a new stamp set, issued by the U.S. Post Office, that featured the highlights of planetary exploration. For Mercury, a stamp showcased *Mariner 10*; a Mars stamp glorified the *Viking* landers. The Jupiter and Saturn stamps featured the trailblazing *Pioneer 10* and *11* spacecrafts, and the Uranus and Neptune stamps focused on *Voyager*. The Pluto stamp said, simply: 'Not yet explored.' [The two engineers] took the Pluto stamp as a call to arms. They didn't know much about Pluto, or its scientific value at the time, but

[34] http://www.ipetitions.com/petition/planetprotest/
[35] http://pluto.jhuapl.edu/overview/piPerspectives/piPerspective_current.php

they damn-well had a fire in the bellies to explore this last frontier[36]!

Although the New Horizons spacecraft has already been launched and can not be brought back to Earth, the mission still needs funding from NASA for at least the next nine years[37]. Pluto is so far away that the spacecraft will not reach its goal until 2015. After its encounter with Pluto there is also the possibility that the mission could be extended by several years to fly past one or more KBOs along its trajectory.

Compare the story of the New Horizons probe with the story of the Dawn Mission[38] that is set to launch in 2007 to study Ceres and Vesta in the asteroid belt. Although the asteroids are much closer to Earth than Pluto, no spacecraft has ever been sent to explore either Ceres or Vesta. The asteroid belt lies in an orbit between Mars and Jupiter. Mars was first explored by the *Mariner 4* spacecraft launched in 1964 and Jupiter was first explored by the *Pioneer 10* spacecraft launched in 1972. One has to wonder if a probe to Ceres wouldn't have been launched before 2007 if it had retained it's status as a planet and the U.S. Post Office had issued a stamp with a note explaining that it too had not yet been explored.

Although NASA makes decisions about its research priorities based on scientific merit, it seems that they also take into account to some degree whether they are sending a probe to explore a planet or to explore something that is not a planet. Since these missions cost

[36] Stern, Alan and Mitton, Jacqueline, "Pluto and Charon: Ice Worlds on the Ragged Edge of the Solar System," p. 185, John Wiley & Sons, Inc., 1998
[37] NASA has stated that Pluto's demotion will not affect its budget for the mission.
[38] http://dawn.jpl.nasa.gov/

hundreds of millions of dollars[39] to design, build and launch, the definition of a planet could have very real consequences for NASA's budget and for those seeking to take part in the designing, building and launching of a mission.

Planetary scientists also have an incentive to have their object of interest be labeled a planet or to have their object of interest not be removed from the list of planets. Career advancement can depend on getting data back from one of these probes. For instance, Pluto is so far away that ground-based telescopes, and even the Hubble Telescope, can determine very little about Pluto's characteristics. A probe will return a stream of data that will be turned into discoveries and publications for those scientists involved with the mission. If your research career depends on having data returned from a certain object, it is reasonable to assume that you would be in favor of anything that would help NASA build a probe to get that data.

In addition to matters of scientific prestige, the status of Pluto is also a matter of national prestige. Pluto was discovered by an American astronomer working at Lowell Observatory in Flagstaff, Arizona and it is the only one of the planets to have been discovered by an American[40]. For the 75th anniversary of Pluto's discovery in February 1930, Dr. Alan Stern wrote an article called 'Pluto at 75: a uniquely American anniversary'[41]. In it he builds excitement for New Horizons by talking about all of the interesting science at Pluto, but he also describes the discovery of Pluto as part of

[39] The total cost of New Horizons is estimated to be more than $600 million and the estimated cost for the Dawn Mission is over $400 million.
[40] Uranus and Neptune were discovered by Europeans and the other planets have been known since before recorded history.
[41] Pluto at 75: a uniquely American anniversary (February 14, 2005) http://www.thespacereview.com/article/319/1

America's historical legacy. Dr. Stern is not alone in promoting Pluto as America's planet. Is national pride motivating scientists to attack or defend Pluto's status? How many of the signers of the petition against the IAU's decision were also American scientists? Would it matter if the IAU were based in the US instead of in France?

Another factor that is influencing the debate is that scientists want to think of Pluto as a planet because that is what they are familiar with. Bowker and Star explain that standards[42] have significant inertia and can be very difficult and expensive to change. In this sense, the complete adoption of a new classification system takes time simply because it will be many years before students taught by new textbooks grow up and replace adults who were taught with old textbooks. Many in the astronomy community think that it is tradition that is the main force shaping this debate today:

> So perhaps the politics and social pressures of the 20th century are not that different in overall character from the politics and social pressures of the 16th century, and some more years must pass before new generations of astronomers fully accept the poor logic behind viewing Pluto as the ninth major planet. Even Galileo (who turned astronomy upside down with his astronomical discoveries in the early 17th century using early telescopes) was unable to accept the assertion by Tycho Brahe and Johannes Kepler that comets orbit the sun (Galileo followed Aristotle's assertion that comets are part of our earth's upper atmosphere, closer to us than the moon). Astronomers are human, too, and many of

[42] Bowker and Star say that classifications and standards are closely related, but not identical. Systems often do become standardized and a standard is in part a way of classifying the world.

them have trouble accepting change[43].

Numerology has played a crucial role in the earlier shifts of planetary classification systems and may still have some small influence today. Bernard Cohen explains numerology's role in the Copernican revolution[44]:

> Numerology had been associated with astronomy and astrology for many centuries before Copernicus, but Copernican astronomy permitted a new basis in numbers to support one system of the world over the other. In the traditional earth-centered astronomy there are seven planets [...] in the Copernican system there are only six[45] [...] It did not take long for a recognition that six is a more appropriate number than seven because it is a perfect number[46].

Astronomers aren't using the same type of rhetoric about numbers today, but there is still a sense that there is a correct number of planets. A solar system with dozens of planets feels wrong to some people (possibly because it would be too many planets for students to memorize). This puts the astronomy community into a Goldilocks[47] situation where some think there are too many planets, some think there are too few and others think the

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[43] http://cfa-www.harvard.edu/cfa/ps/icq/ICQPluto.html

[44] I. Bernard Cohen, "G. D. Cassini and the Number of the Planets" in Nature, Experiment, and the Sciences, ed. by T. H. Levere and W. R. Shea

[45] Johannes Kepler, who formulated the laws of planetary motion, also identified the five Platonic solids with the five intervals between the six known planets (Mercury, Venus, Earth, Mars, Jupiter, and Saturn) and the five classical elements.

[46] A perfect number in mathematics is one that is equal to the sum of its divisors (1 + 2 + 3 = 6).

[47] 70 Virignis b is an extrasolar planet that has been nicknamed Goldilocks because astronomers feel that it is orbiting in the perfect spot where life might develop since it is neither too close to the star and too hot or too far away from the star and too cold.

number of planets is just right.

Closure Mechanisms

The IAU is composed of professional astronomers from around the world with the mission to reach consensus about issues among the community. How will the IAU be able to respond to the current controversy and reach a consensus among its members about the definition of a planet and Pluto's status? H. M. Collins suggests that this argument among members of the astronomy community is an essential part of the resolution process:

> Core sets [the scientists of a discipline engaged in a controversy] certify new knowledge. From the outside they appear to be simply the 'group of scientists' who are investigating a potentially novel feature of the universe. […] The knowledge which emerges from a core set is the outcome of an argument that may have taken many forms not normally viewed as belonging to science. […] Some 'non-scientific' tactics *must* be employed because the resources of experiment alone are insufficient. […] Nevertheless, the outcome of these negotiations, that is, certified knowledge, is in every way 'proper scientific knowledge'. It is replicable knowledge. Once the controversy is concluded, this knowledge is seen to have been generated by a procedure which embodies all the methodological proprieties of science. […] Core sets funnel all of their competing scientists' ambitions and favoured alliances and produce

> scientifically certified knowledge at the end[48].

The petition that was signed after the IAU passed their resolution makes it clear that the official IAU definition will be ignored by at least some in the community: “We, as planetary scientists and astronomers, do not agree with the IAU’s definition of a planet, nor will we use it. A better definition is needed[49].” This is not a new problem for the standards setting body. Compare the petition with the Hayden Planetarium’s unilateral demotion of Pluto six years before the IAU passed its resolution. When the Rose Center for Earth and Space at the American Museum of Natural History in New York City opened in 2000 there were 8 planets in their displays, starting with Mercury and ending with Neptune[50]. Dr. Neil de Grasse Tyson, director of the museum, was quoted as saying "We're not that confrontational about it. You actually have to pay attention to make note of this. [...] I'm convinced our approach will prevail. It makes too much scientific sense and too much pedagogical sense."

Catherine Cesarsky, the president of the IAU, gives her perspective of this controversy:

> We knew in advance that no matter how this decision would come out, a part of the astronomical community would be disagreeing. The intense debate at the 2006 General Assembly was very healthy and exactly intended to make as large a fraction of the community as possible agree

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[48] Collins, H.M., "Changing Order: Replication and Induction in Scientific Practice," page 143, The University of Chicago Press, 1992

[49] http://www.ipetitions.com/petition/planetprotest/Petition_Release_Planet.pdf

[50] Planetarium Takes Pluto Off Planet A-List (January 22, 2001) http://www.nytimes.com/2001/01/22/science/22PLAN.html

> with the decision. In this we succeeded. It also has to be said that the - now very visible - "splitting" of the community in the issue of where to make the delineation between planets and other solar system objects is not new. It is a debate that has existed for several years[51].

The IAU's next General Assembly is scheduled for 2009 and Pluto proponents are already preparing for it:

> The IAU is incapable of correcting this action until its next General Assembly in 2009. In the meantime, the IAU definition will stand as a source of confusion and incongruity to educators and the public. An alternative is needed. Planning is underway to establish an open and inclusive grass-roots process by which planetary scientists and astronomers from around the world can approach a better resolution to the issue of planets in our own solar system and elsewhere, with every step and discussion in public view. This process should culminate in a conference, not to determine a winner, but to acknowledge a consensus. The discussion will be wide ranging and should offer the public a fascinating and educational view of scientific discourse on a topic to which they can all relate[52].

In the end, the dispute will be over and done with when the scientists are no longer

[51] Interview with the IAU President on Pluto's Demotion (September 11, 2006) http://space.com/scienceastronomy/060911_cesarsky_qanda.html

[52] http://www.ipetitions.com/petition/planetprotest/

debating this matter at meetings of the IAU General Assembly. Although it is impossible to say which side will win, it is clear that non-scientific factors such as the petition against the current definition will be brought in to play by both sides. “Any […] tactic or exercise of power is usable and used within the core set in order to bring about a favorable ‘closure’ of the debate. These are the individual’s contributions to changing and maintaining order[53].”

This apparent intrusion of politics into the realm of science is disturbing for some people involved in the current debate since the scientific method says that this controversy should be resolved through an objective and rational process. It is only during times of scientific crisis though that it is possible to see how subjective factors can shape science:

> Once the scientific truth is known it is forgotten that non-experimental and ‘non-scientific’ negotiating tactics were necessary if closure was to be attained. The magic of the core set lies in the way it uses anything to make a scientific fact yet also renders all the ingredients invisible to all but the very determined investigator[54].

In the news and scientific articles about Pluto’s status, there are repeated references to the idea that there is no room for social and political factors in this debate. For instance:

> If scientific decisions are to be henceforth based on the whim of culture,

[53] Collins, H.M., "Changing Order: Replication and Induction in Scientific Practice," page 151, The University of Chicago Press, 1992

[54] Collins, H.M., "Changing Order: Replication and Induction in Scientific Practice," page 152, The University of Chicago Press, 1992

> it is time for astronomers to pack up their telescopes and go back to dreaming up stick figures out of random star patterns. And while we're at it, perhaps we should consult religious leaders for their opinions on how to interpret the results of astronomical observations[55].

And:

> The important thing to remember is that the new definition was established by a vote, making it politics, not science[56].

And:

> Astronomy does not work that way -- things are often re-classified or discussed in different ways in the light of new knowledge (and "demotion" is simply a political, not realistic, word used by Pluto-is-ninth-planet proponents in the United States)[57].

These comments are completely understandable because in the case of Pluto science isn't working the way we have been taught that it should. In the end, it is the dispute resolution process itself that may be the biggest reason why people are so upset over the status of Pluto.

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[55] http://www.livescience.com/blogs/2006/04/11/demote-pluto-and-kill-xena/
[56] Pluto: Down But Maybe Not Out (August 31, 2006) http://www.space.com/scienceastronomy/060831_planet_definition.html
[57] http://cfa-www.harvard.edu/cfa/ps/icq/ICQPluto.html (This quote coming from an author who has classified Pluto as a minor planet)

Conclusion

The history of planetary astronomy shows that technology is excellent at raising new questions, but it is the astronomers themselves, and not the telescopes, who have to answer those questions.

When the New Horizons probe reaches Pluto in 2015 its sensors and cameras will be of no use in resolving the controversy about the object's status. The probe will be able to measure Pluto's chemical composition, surface temperatures and albedo, but there is no test for planet-ness that can be performed. A planet is defined by the people studying those objects and both non-scientific factors and scientific characteristics are used as part of the classification system that is chosen by the group.

The astronomy community is having difficulties fitting the new objects they have discovered into their current classification systems. Since there is no generally agreed way to classify these new discoveries, there are now many competing and overlapping categories that are being proposed by various astronomers, not just for the major planets, but for minor planets and extrasolar planets as well.

If the astronomy community is in the middle of a crisis that is provoking a paradigm shift, Kuhn and Collins state that the debate about the scientific logic of the new classification system will only be resolved after the new system has been agreed on. In the middle of this transition, many people are shocked by the influence of non-scientific factors in the debate. After the transition is over though, the scientific merits of the agreed upon system will be obvious – a planet will be a planet because that is what it is. We will return to a time when the arbitrary classification system is not visible, because no one in the community will be questioning why one object was put into the box labeled 'planet' versus a different one.

So this debate surrounding Pluto is more than just a scientific disagreement about the place of Pluto in the solar system. The process of defining a planet will also shed light on how classification systems are created in other disciplines and how both scientific and non-scientific factors turn a clean idealized system into a messy real-world system.

This process might also shed light on the scientific practice of mnemonic devices. If our children are taught that there are 8 planets then My Very Educated Mother Just Served Us Nectarines could be a good fit. If the definition of a planet is changed at the next IAU General Assembly meeting in 2009, there could end up being dozens of planets. At that point, coming up with a mnemonic device that includes Sedna, Quaoar, Ixion, Varuna and Eris will be an important discovery in its own right.