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ABSTRACT In 2006, for the first time in its history, the International Astronomical Union defined the characteristics of a 'planet' in our Solar System and consequently demoted Pluto from 'planet' to 'dwarf planet'. Scientific and popular discussion leading up to and following the formal definition of planet demonstrated that astronomers, amateurs, educators, and school children had been employing Pluto in different ways to construct multiple scientific and cultural cosmologies. Formalizing the definition brought these cosmologies into direct collision, necessarily privileging some cosmologies over others. The story of Pluto, from discovery to demotion, illustrates the discursive disruption that stemmed from forced consensus. Before 'planet' received a formal definition, it was a tacitly understood term that encompassed several meanings and acted as part of the contact language in a trading zone, as described by Peter Galison. Social groups were able to clearly communicate using the word 'planet' despite differing cosmologies. This paper takes a closer look at Pluto's history, highlighting three moments when Pluto's planetary status was challenged. Each moment – a controversial exhibit opening that excluded Pluto from the planetary display, the discovery of objects in the Solar System larger than Pluto, and the International Astronomical Union conference at which astronomers crafted the definition of planet – spurred discourse that accentuated conflicting cosmologies. Actors involved in these incidents directed the discussion in order to maintain clear communication or to make sure their cosmologies remained relevant. Only with the formal definition of planet, which excluded several popular and scientific cosmologies and shifted discussion about classification in our Solar System from a prototypical to an Aristotelian language, was Pluto demoted.

Keywords classification, controversy, planetary science, Pluto, trading zone

The Problem with Pluto:

Conflicting Cosmologies and the Classification of Planets

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> **to pluto/be plutoed**: to demote or devalue someone or something, as happened to the former planet Pluto when the General Assembly of the International Astronomical Union decided Pluto no longer met its definition of a planet. (American Dialect Society's Word of the Year, 2006)

At the Museum of Science in Boston, the astronomy exhibit is located in a small, dark room outside the entrance to the museum's planetarium. At the

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far end of the room, an orange, glowing sun protrudes from the wall. Along a single arc that traces the Sun's equator, there are nine stations, one each for Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. At each station there is a phone that one can pick up to hear information about the planet. There is also a flipbook of statistics about the planet's orbit, moons, and atmosphere. At the Pluto station, however, there is a plaque nailed over a now empty flipbook cubby informing the visitor that 'In August 2006, the International Astronomical Union passed a resolution defining a planet in such a way that Pluto no longer qualifies. As a result, the Solar System now consists of 8 "classical" planets. Pluto now belongs to a newly defined class of objects called "dwarf planets".' This plaque does not share with the visitor Pluto's rich history and how the definition of *planet* emerged from a complex exchange between sub-disciplines within astronomy; an exchange shaped both by astronomers' expectations of the cultural impact of reclassifying Pluto and by the voices of amateurs, science educators, and enthusiasts. This paper tracks the discussion around Pluto, drawing attention to the ways in which disciplinary conflicts and public expectations fashioned the 2006 definition of *planet.*

Clyde Tombaugh discovered Pluto in 1930. Astronomers who were studying the orbits of Uranus and Neptune predicted that Pluto was at least as big as Earth and immediately classified it as the ninth planet. Pluto quickly rose to the status of a public icon, embraced by Americans as the first planet discovered by one of their own countrymen. Astronomers aided by refined instrumentation, continued recalculating Pluto's mass and orbit. By the end of the 20th century, they concluded that Pluto was quite tiny, only a fraction of the size of the moon, and it was not the only body orbiting the edge of the Solar System. Discoveries of Pluto's three Moons (Charon, discovered in 1978; Nix and Hydra, discovered in 2005), as well as of new bodies in the 1990s confirmed the existence of a densely populated zone that came to be called the Kuiper Belt. The Kuiper Belt is a clustering of small icy objects that, like Pluto, follow eccentric and highly elliptical orbits around the Sun. As Pluto's size diminished and discoveries of closely orbiting Kuiper Belt Objects (KBOs) proliferated, astronomers began discussing whether Pluto acted more like a KBO or a planet (see for example Marsden, 1980). Astronomers were able to avoid definitively resolving this question because, despite its new neighbors, no KBO was larger than Pluto.

In 2003, an astronomer discovered an object in the Kuiper Belt that was more massive than Pluto. Was this a tenth planet or a KBO? If it were to be classified as a KBO, might not Pluto also be reclassified as one? These questions, well articulated by Tytell (2005), prompted the International Astronomical Union (IAU) to create a Planetary Definition Committee to formalize the definition of *planet*. The membership of the IAU convened in August 2006 and among the many presentations was one on a definition composed earlier that summer by the Committee. During the conference, discussion and debate transformed the Committee's proposed definition of *planet* – which stated that a planet was any round object orbiting a star

(including Pluto, round KBOs, and the round asteroid Ceres) – to one that only counted objects that were round *and* dominated their orbital paths ('cleared the neighborhood around its orbit' in the language of the definition). Because KBOs swarm around Pluto, Pluto did not satisfy the second criterion. This definition, approved by a show of hands of the 420 IAU members who attended the closing conference session, reclassified Pluto as a 'dwarf planet' – a body orbiting the Sun that is round but *is not* the dominant body in its orbit. The definition clearly states that there are only eight planets in the Solar System, and 'further resolves that Pluto is a "dwarf planet" … and is recognized as the prototype of a new category of trans-Neptunian objects' (International Astronomical Union, 2006).

This narrative of Pluto's reclassification comes into focus when examining more closely the distinct classification systems that different participants employed, and it also underscores the fact that those involved in this debate about natural classification knew that their choices would have non-trivial social effects. Competing classificatory systems are central to various *scientific and cultural cosmologies*, the terms I use to indicate tacit understandings of the Solar System. When a new classification scheme is proposed which necessarily privileges one cosmology over another, narratives such as the one above become laced with discursive instabilities.

Research in the history and social study of astronomy has centered on themes such as the social and intellectual trajectories of the field and emerging subfields (Edge & Mulkay, 1976; Lankford, 1997) as well as astronomy's relationship to NASA and the dynamics of politics and funding (Tatarewicz, 1986; Logsdon, 1989; McCray, 2000; Mellor, 2007). Several studies discuss the heterogeneity of astronomical practice and the role of amateurs (Lankford, 1981a,b; Rothenberg, 1981; Schaffer, 1988; McCray, 2008) and discuss astronomy's interaction with the public by analyzing discourse about images taken by Hubble or during the Apollo program (Cosgrove, 1994; Greenberg, 2004; Jasanoff, 2004). A less explored dynamic, and one that this paper takes as a central theme, is how amateur and public attitudes and actions have influenced (as opposed to passively supplemented) the professional discourse.

In what follows, I show how Pluto became differently embedded in cultural and scientific cosmologies. Three episodes in which Pluto's planetary status was threatened – the 2000 reopening of the American Museum of Natural History's planetarium, the discovery of the KBO larger than Pluto, and the 2006 IAU conference – each illustrate how different sets of social groups fought over Pluto's classification.[1] Ultimately, the approved definition of planet introduced a rigid classification system that favored some cosmologies over others. I conclude by discussing professional and public reactions to the new definition of planet.

Science studies scholars have developed several frameworks to discuss scientific discourse and interaction. Boundary objects (Star & Griesemer, 1989) and trading zones (Galison, 1997) are models of coordination stemming from the observation that heterogeneity does not necessarily impede communication. The trading zone metaphor comes from anthropological

observations of how local coordination between peoples with different symbolic and cultural systems is made possible at agreed upon regions of trade. Galison applies the concept of the trading zone to the field of physics as a means of explaining local cooperation between sub-disciplines despite global differences. Similarly, boundary objects are concrete or abstract objects or ideas that are used by multiple social groups. Different groups attach different meanings to a boundary object; however, it has enough robustness to translate across boundaries and be meaningful in discourse. Galison's emphasis on the role of language makes the trading zone a pertinent metaphor when discussing the process of defining terms. Coordination in the trading zone is helped along by contact languages (pidgins and creoles), which facilitate communication without the need for 'full-blown translation' (Galison, 1997: 833).[2] *Planet* is an example of a term once flexible enough to facilitate conversations, allowing social groups to discuss the Solar System despite differing cosmologies. What happens, however, when this language of coordination becomes itself the focus of discourse? When *planet* could no longer be part of the contact language, when Pluto ceased to be a boundary object, when coordination efforts were interrupted, how were discourse and interactions affected?

Prior to its formal definition, *planet* was smoothly traded between sub-disciplines within planetary astronomy. *Planet* fits into several scientific cosmologies. The proceedings of the IAU conference accentuated a stark contrast between the cosmologies of two sub-disciplines: structuralists and dynamicists. For dynamicists, those who study how celestial objects move, Pluto's orbit and how it interacts with local objects are part of a *dynamic cosmology*. For dynamicists, the definition of planet would need to include an element of motion. Structuralists, on the other hand, are primarily interested in what objects are made of; they study Pluto's atmospheric and tectonic attributes. To satisfy a *structural cosmology,* the definition of planet would need a material component. Defining *planet*, an act of 'full-blown translation', made it apparent that the sub-disciplines had attached different global meanings to the word *planet*. If the act of translation could succeed in representing both cosmologies, perhaps the trading zone would remain intact. If one global meaning were to be prioritized over the other, the trading zone would be undone and coordination consequently disrupted.

The balancing act between structural and dynamic cosmologies only partially explains the discourse at the IAU meeting. Not only was there a decaying trading zone between sub-disciplines, but there was also one between the profession and those outside the profession. The language of the definition of *planet* was shaped not only because of attempts to balance the structural and dynamic cosmologies, but also because of moves made to balance the scientific cosmologies with a *cultural cosmology*. Cultural cosmologies broadly encompass lay understandings that there are nine planets in the Solar System, with each planet having an associated mythology that gives it a personality, and with Earth as unique among the planets. Pluto takes its place within this cosmology as the endearing underdog and oddball.

Astronomers who were concerned that the lay audience would be alienated or upset if the definition of planet was too technical or if Pluto was no longer a planet sought to preserve the cultural cosmology within the new definition. Not all astronomers at the IAU meeting agreed that the cultural cosmology should be given equal weight to the scientific cosmologies. This disagreement stimulated discursive effects that further shaped the definition.

Until 2006, Pluto could fit comfortably into multiple cosmologies because *planet* lacked a formal definition and could be used as a term of exchange within trading zones internal and external to astronomy. Defining *planet* and establishing a formal classification system of objects in the Solar System explicitly embraced some cosmologies while rejecting others. Prior to 2006, astronomers sorted objects in the Solar System using a prototype (gestalt) system. In prototype systems, one classifies an object by identifying it with a best example – something it most resembles (Bowker & Star, 1999: 62). Thus, different groups classify objects in different ways. If an astronomer decides the best example for Pluto is Earth, then it is a planet. A different astronomer might consider the best example to be a KBO. This variation allowed astronomers to test different theories while working towards more sophisticated understandings of the Solar System. But the classification system spelled out in the definition of *planet* in 2006 ordered objects of the Solar System via an Aristotelian (necessary and sufficient) classification system. An Aristotelian system classifies based on binary qualities (orbiting the Sun or not orbiting the Sun; round or not round; dominant object in orbit or not dominant object in orbit) and leaves less room to experiment with alternative groupings. Formalizing the classification system within a trading zone made explicit the heterogeneity on which cooperation thrived. In doing so, the trading zones broke down because not every prototype system could be incorporated. Further, the resolution that there are now only eight planets in the Solar System excluded the prototypically infused cultural cosmology.

This is not the first time that a changing classification system was of interest to the general public (see Gould, 1992, for the story of the brontosaurus; Ritvo, 1997, for broader discussion of natural history classification and publics; and Dupré, 1999, for the interplay between folk and scientific taxonomies in the debate over whether the whale is a fish or mammal). Pluto's case diverges from other studies of classification, however, because many astronomers did not mask the social nature of the task. At times, astronomers even abandoned the rhetoric of scientific objectivity in favor of highlighting a powerful cultural intuition and expectation of what constituted a planet, linking prototypical language with cultural cosmologies. The chair of the definition committee stated that the committee's task was to create a 'scientific, but culturally sensitive definition' (Gingerich, 2007: 136). Astronomers who were engaged in the debate repeatedly deployed their own understandings of cultural cosmologies both to argue for the preservation of nine planets and, conversely, invoked Aristotelian language to point out that such cultural sensitivities had no place in what should be a scientific discussion.

Tracking the controversy over Pluto's status and the definition of *planet* highlights the interactions and influences that groups inside and outside the profession have on the astronomical discourse. Observing the way classification plays a disruptive role makes us rethink the construction of knowledge in astronomy by creating a higher-resolution picture of whose cosmologies are at stake.

Humble Beginnings

The discovery of Pluto was neither a product of serendipity nor an accident. Rather, it was the culmination of a tedious effort to find 'Planet X', predicted by astronomer Percival Lowell (1915), known for his theory of Martian canals. Planet X was a body theorized to be more massive than Earth, orbiting beyond Neptune and causing the perturbation astronomers had observed in Uranus's orbit. The search for this Planet X began in 1905 and was not successful until years later when Clyde Tombaugh, an amateur astronomer[3] with a meticulous disposition, gained photographic proof of an object in the predicted orbit of the hefty Planet X. On 13 March 1930 (the 75th anniversary of Percival Lowell's birth) Lowell Observatory announced Tombaugh's discovery. The newly discovered Planet X, thought to be bigger than Earth, needed a name.

Astronomical custom dictated that the discovering organization (Lowell Observatory) had naming rights. During the weeks following the announcement of a ninth planet, dozens of suggestions for its name were proposed by astronomers and other scientists, and in letters to the editor in local and national newspapers.[4] An 11-year old British girl, Venetia Phair, is supposedly the first to have suggested Pluto (Stern & Mitton, 2005: 16). Members of Lowell Observatory narrowed the names down to Minerva, Cronus, and Pluto. Minerva was a favored name because it symbolized both the wisdom and reason of Lowell whose mathematics predicted the ninth planet *and* the handicraft of Tombaugh whose persistence to sort through the photographic plates yielded the discovery. However, members of the Lowell Observatory ultimately voted in favor of Pluto, god of dark, distant regions, because Minerva was already the name of an asteroid. When the name was announced on 25 May 1930, a trustee of the observatory further noted that the first two letters of Pluto served as a memorial to the planet's first advocate, Percival Lowell (*New York Times,* 1930c,d). This homage to Lowell, the interest of the media in the name selection, and the role of Phair were early indications that the ninth planet was not exclusively in the realm of professional astronomers.

Walt Disney brought Pluto further into the American public vernacular by giving the name to a cartoon character. Pluto the Pup's first animated appearance was as an unnamed hound in a Mickey Mouse cartoon that aired several months after Pluto the Planet's discovery. He was formally named in 1931. There is no official story as to how the character received his moniker, though animation historian John Canemaker (2004) claims that it was named after Walt Disney's own pet dog. But regardless of naming origin, the dog has since become strongly associated with the planet.[5]

While Pluto the Pup rose to fame, its namesake soon became a source of confusion and embarrassment for planetary scientists. In the decades after 1930, as observational instrumentation improved, Pluto's mass was recalculated. Instead of being seven times more massive than Earth – the mass needed to explain the Uranus perturbation – observations between the 1930s and 1950s predicted Pluto to instead be more comparable in size to Earth. Even with this decreased mass, however, Pluto was still considered dynamically significant.

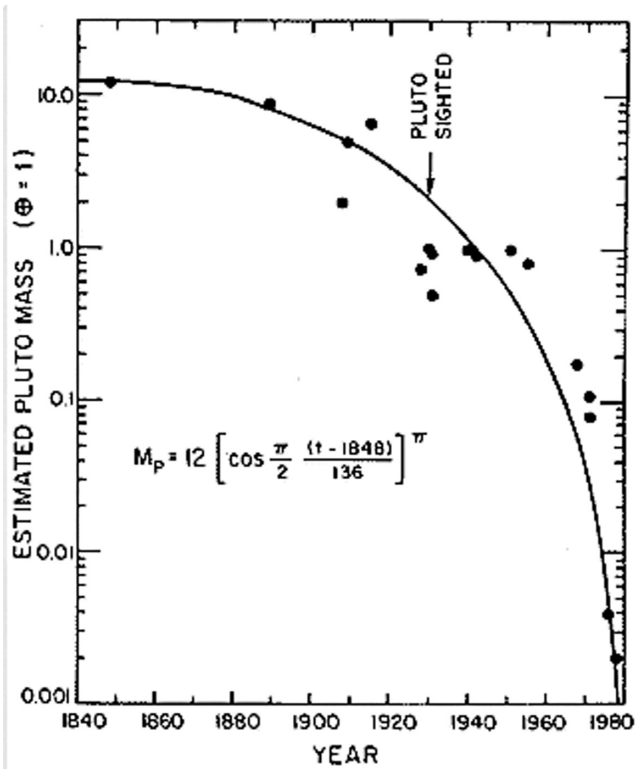
In 1968, after mass calculations could be performed with high-speed computing, Pluto's size dropped to a range of 0.1 to 0.2 Earth masses. Finally, in 1978 astronomers concluded that Lowell's prediction and Tombaugh's observation were coincidences. The discovery of Charon, an object orbiting around Pluto, firmly established that Pluto weighed only 0.002 Earth masses making it less massive than Earth's Moon. The paper documenting the discovery of Pluto's satellite cautiously suggests: 'Thus, Pluto is certainly not a terrestrial-type planet, and very possibly may not have originally been a planet at all' (Christy & Harrington, 1978: 1008). Astronomers did not know whether to be amused or embarrassed over the repeated miscalculations of Pluto's mass. Two astronomers wrote a paper in 1980 for *Eos, Transactions* (the journal of the American Geophysical Union), humorously arguing that previous mass estimates for Pluto should be taken seriously and used to predict the 'impending disappearance of Pluto', which they slated for 1984 (Dessler & Russell, 1980; Fig. 1). Ironically, they were only a couple of decades off from predicting the semantic elision of Pluto as a planet.

In the same year, two other astronomers summarized Pluto's journey in a more serious manner:

> Two conclusions can be drawn from this evidence: (1) while all credit must be given to Percival Lowell for initiating, and providing the impetus for, a search for planet X, the subsequent discovery of Pluto seems due entirely to the thorough and painstaking search made by Clyde Tombaugh. … (2) The new mass of Pluto effectively removes it as a source for the anomalous residuals observed in the motion of Uranus and Neptune. Apparently, our model of the outer solar system remains incomplete. (Duncombe & Seidelmann, 1980: 18)

This paper appeared in the Fall 1980 issue of *Icarus* (a leading journal of planetary science), celebrating 'Pluto – The Ninth Planet's Golden Year'. The issue contained retrospective papers by Clyde Tombaugh (who, following his discovery, received his bachelors and PhD in astronomy) and other astronomers summarizing Pluto's scientific history. Not all papers were celebratory. Brian Marsden, invoking language of prototypical classification, boldly asked, 'is it therefore perhaps not time we dropped the appellation "ninth planet" and *classified* Pluto with the two objects it most obviously resembles [Chiron, located between Saturn and Jupiter, and Hidalgo, in the asteroid belt], as an unusual minor planet?' (Marsden, 1980; emphasis in original). Marsden served as the director of the Minor Planet

FIGURE 1
Change in Pluto's mass over time 'Estimated mass of Pluto as a function of time. The black circles are experimental data; the equation is plotted as the solid line, which is the best-fit curve on which the theory is developed' (Dessler & Russell, 1980).



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Center (MPC) from 1978 until 2006. The MPC, overseen by the IAU and based at the Harvard-affiliated Smithsonian Astrophysical Observatory, is the organization responsible for cataloguing small solar system bodies (such as asteroids and objects beyond Neptune's orbit). Marsden was one of the earliest documented proponents for the demotion of Pluto. It is worth noting that Marsden's goal of reclassifying Pluto as a minor planet would place Pluto within the jurisdiction of Marsden's own institution. In the same way that non-astronomers (Phair and Disney, for example) pulled Pluto into their domains, the professional community now engaged in a similar sub-disciplinary tug of war – a tug of war that would culminate in the debate over the very definition of *planet* itself.

Astronomers began occasionally to engage with Marsden's argument that Pluto belonged to a different category. Not every astronomer's impulse was to demote. In 1991, S. Alan Stern published a prediction that the number of planets in the Solar System was likely to be much larger than the accepted nine. To argue this point, he first proposed a definition of planet as

something large enough to pull itself into a ball (hydrostatic equilibrium) but small enough that it doesn't produce its own energy through nuclear fusion (note that this is a purely structural definition, saying nothing about the object's orbit). Stern then predicted that a population of planets would exist in a region called the Kuiper disk, a zone that begins just beyond Neptune's orbit, at 30 astronomical units (AU), and extends to 500 AU.[6] Stern hypothesized that the likely discovery of bodies in this disk would be crucial to studying the origin of the Solar System. He went on to state that 'Triton [Neptune's moon], Pluto, and Charon … likely represent the only relics of this ancient population that are permanently preserved in the 20–50 AU region … the population of comets and 1000 km bodies there is not large' (Stern, 1991: 280).

Though this last assertion ended up being incorrect (the population in this region is quite large), Stern not only advocated accepting Pluto as a planet; he also expected more Pluto-like planets to be discovered in the future. At the time he wrote this paper, his professional stakes were considerably lower than they would be when Pluto was formally demoted and he was the principal investigator of NASA's New Horizons mission, a probe en route to Pluto and the Kuiper Belt.

Yet Stern's prediction of other outer planets, like Marsden's speculation that Pluto was a member of a different class of objects, lacked empirical evidence. That changed in 1993 when astronomers Dave Jewitt and Jane Luu (1993) announced in *Nature* the existence of the object 1992 QB_1, proving the existence of the theoretical Kuiper Belt. The object 1992 QB_1 orbits at 40 AU (and thus within the region Stern had insisted would be empty). In the years that followed, hundreds of KBOs were (and are still being) found in the 30–50 AU region. The dynamic and structural similarities between the growing population of KBO's and the Pluto–Charon system led many astronomers to finally agree with Marsden's hypothesis that Pluto should not belong to the category of planet, but to the category of KBO – a class of minor planets.

The astronomical literature in the 1980s, 1990s and early 2000s contains an abundance of terms used to describe objects at the outskirts of the Solar System: KBOs, trans-Neptunian objects (TNOs), minor planets, plutinos, centaurs, and cubewanos. These categories are not discrete; objects have multiple memberships, and different astronomers adopt different nomenclature. For example, a paper discussing two objects (Ixion and Quaoar), refers to both as TNOs and members of the Edgeworth–Kuiper belt. Ixion is also described as being similar to centaurs, while Quaoar is closer to a cubewano. These classifications are made based on visible spectroscopy, a method used by both structuralists and dynamicists because it can provide information about an object's composition and dynamical history (Marchi et al., 2003). In another paper (also using visible spectroscopy) from the same journal, Ixion is called a KBO, TNO, and plutino (Boehnhardt et al., 2004). The fluidity of language used to describe these distant objects reflects a prototypical approach to classification. Astronomers were identifying objects with a best example rather than using a binary system. Further, the sharing of empirical data despite theoretical differences

is a classic example of the function of a trading zone – making it possible for Boehnhardt to cite the spectra data from Marchi despite a different classification of Ixion.

Planet was still part of the contact language in the trading zone between sub-disciplines, though from as early as the 1980s astronomers were aware of how Pluto complicated the concept of *planet*. Astronomers increasingly recognized that *planet* should be treated more as a theoretical construct than an a priori object or a natural kind. Though this problem percolated through the theoretical discussion, at the experimental level astronomers who worked Pluto into the Solar System's planetary system and those who placed it among the KBOs continued to share data. There was a trading zone between sub-disciplines, which operated as 'an intermediate domain in which procedures could be coordinated locally even where broader meanings clashed' (Galison, 1997: 46). Multiple, even contradictory, scientific cosmologies could exist without hindering communication about objects in the Solar System.

Where's Pluto?

Though astronomers were testing the meanings of *planet* in the occasional journal paper, this ambiguity had not yet touched public discourse and *planets* continued to be understood in classrooms and popular science books as objects in our Solar System that numbered nine. *Planet*, lacking a formal definition, had the flexibility to be at once controversial (for astronomers) and benign (for the lay audience). Jordan Marché's history of 20th century planetaria claims that 'the transmission of knowledge from research astronomers to the public remains the primary social function of the planetarium' (Marché, 2005: 2). In addition to planetarium shows, astronomers often provide observational information to enthusiast sky watchers in popular astronomy magazines. In 1993 and 1994 there was a monthly column in *Natural History*, a magazine published by the American Museum of Natural History (with which the Hayden Planetarium is affiliated), telling readers where in the night sky each of the nine planets could be located. *Planet* could be used to communicate clearly with lay audiences, even though the cultural meaning of planet was beginning to diverge from how the term was being used in the astronomical community. Why was there this commitment to the cultural cosmology of nine planets, and more specifically to Pluto's status as the ninth planet?

Dava Sobel (2005) attempts to pinpoint why we are so fond of the underdog Pluto: 'Children identify with its smallness. Adults relate to its inadequacy, its marginal existence as a misfit.' When Pluto was first discovered, a newspaper article described the new planet with empathy: 'Way out beyond Neptune, tagging bashfully behind its brothers' (*New York Times*, 1930a). Astronomer Arthur Eddington also commented on the early attachment to Pluto: 'On the whole, popular interest in the new planet's discovery may be said to be romantic rather than scientific' (*New York Times*, 1930b). In the classroom, teachers anchored Pluto in the minds of school children through the popular mnemonic device 'My Very Educated Mother

Just Served Us Nine Pizzas.' This phrase, like 'King Philip Came Over For Good Soup' (kingdom, phylum, class, order, family, genus, species), is associated with the grammar school pedagogy that emphasizes (however falsely) objective and static characteristics of science.

When this pedagogy was publicly challenged at a planetarium at the turn of the millennium, museum-goers reacted negatively. In February 2000, the Hayden Planetarium at the American Museum of Natural History (AMNH) in New York re-opened after three years of renovation. The Planetarium's director, astrophysicist Neil deGrasse Tyson, decided to exclude Pluto from the planetary display. When a *New York Times* article pointed out Pluto's absence, Tyson was bombarded with criticism and letters from children and parents requesting that he put Pluto back on display.

In February 1999, prior to the re-opening of the Hayden Planetarium, Tyson explained his rationale for the proposed unorthodox display in *Natural History*:

> Alas, Pluto … is none other than a Kuiper belt object – a leftover comet from the solar system's formation. If Pluto's orbit were ever altered so that it journeyed as close to the Sun as Earth, Pluto would grow a tail and look like a jumbo comet. No other planet can make this (possibly embarrassing) claim. Just as Ceres went from being the smallest planet to the biggest asteroid, so too must Pluto be reassigned from its 'smallest planet' status to the biggest object of a new class. (Tyson, 1999)

Tyson's framing was careful. He explained his decision to remove Pluto from the planetary pack as something Pluto would want – finally Pluto can be a big fish in a little pond instead of the 'embarrassing' runt of the family. This consideration of Pluto's feelings placed alongside the astronomical language of KBOs illustrates an attempt to combine cultural and scientific cosmologies to propose a system of classification. Despite this tack, the letters to the editor (authored by enthusiasts and professionals) printed in *Natural History* following this announcement were all in opposition. Each objection shows how Tyson's system excluded other cosmologies. One letter to the editor, whose author jokingly named himself founder and president of the Pluto Planetary Protective Society, rejected this inductive reasoning and called Pluto's demotion 'premature' until a mission has been sent to the Kuiper Belt (Kane, 1999). Two letters advocated a stronger commitment to the cultural cosmology by suggesting Pluto be grandfathered in or promoted to an Honorary Planet (Senn, 1999). 'Stripping Pluto of its planethood is like stripping George Washington of his citizenship because the United States wasn't a country when he was born' (Leece, 1999). Pluto should be a planet, they suggest, not because of science per se, but because of expectation, tradition, and precedence. Finally Stern – who, as noted above, was in favor of increasing the number of planets – wrote that one of Tyson's structural reasons for demoting Pluto (its icy composition) is false. Pluto is 70% rock (Stern, 1999). These letters foreshadow the arguments raised in Prague in 2006 when the contact language deteriorated due to the articulation of similar conflicting cosmologies.

How was Tyson's proposed system of classification displayed? When the Hayden Planetarium re-opened within the Rose Center for Earth and Space, there was no place where nine planets (or even eight planets) were installed. Instead, the main objects of the Solar System were presented as terrestrial planets and gas giant planets. The Kuiper Belt was presented as a separate family of 'small, icy worlds including Pluto'. Therefore, Pluto was not presented as a planet, but it also didn't explicitly lack planetary membership (and it retained some cachet by being described with the prototypical language of 'world'). Tyson claimed that this classificatory regime was not meant to be devious, but instead to present the Solar System in an organized way that made Pluto's classification self-evident. However, this ambiguity was a bit too subtle, for it was not until Pluto's place in the exhibit received front-page coverage by the *New York Times* in January 2001 ('Pluto not a Planet? Only in New York') that museum visitors and astronomers not part of the discussion in *Natural History* expressed confusion and annoyance over the display. When one visitor was asked what she thought about the exhibit, she explained how she had to go through the mnemonic device to figure out which planet was missing. A museum educator said that children had been the most likely to ask after Pluto (Chang, 2001a). Following this article, Tyson received hundreds of emails and letters from non-astronomers declaring their devotion to the planet Pluto (Tyson, 2009).

Several astronomers responded with disappointment to the museum's presentation of the Solar System. In the same *New York Times* article, Richard Binzel, a planetary scientist at MIT, said that the exhibit 'went too far in demoting Pluto, way beyond what the mainstream astronomers think'. Stern, also quoted, emphasized this point by calling the museum's presentation of Pluto 'a minority viewpoint'. One striking aspect of these statements by astronomers is the repeated invocation of a language of democracy (minority and majority viewpoints). A printed conversation between Tyson and Mark Sykes, the Chair of the Division for Planetary Sciences of the American Astronomical Society, further evidences the rhetoric of minority and majority. Sykes stated that there are very few astronomers (he can count them on one hand) that would agree with the museum's presentation. Sykes further surmised that if Pluto were discovered today, the fact that it has a moon and an atmosphere would certainly qualify it as a planet. Sykes admitted that some of his contemporaries might disagree. Tyson corrected him, 'Not a few, but many [would say that Pluto's status as planet is a product of history, not science]. Because there's some legacy thing going [on], because of course we've lived with it for 60 years, and there's a dog named after it. It's in our culture. It's here.' Sykes responded, 'There are noncultural things [that qualify it as a planet] .... It's got nitrogen ice caps. It's got seasons.' The allusions to seasons, moon, and atmosphere make Pluto different, more special – more earth-like and thus prototypically similar to a planet. Because more is known about Pluto than other KBOs, Sykes called Tyson irresponsible, from an educational standpoint, to lump Pluto with 'these other guys' (Sykes & Tyson, 2001).

After this conversation with Tyson, Sykes addressed the Division for Planetary Sciences and concluded that what the AMNH ultimately presented to the public was not a controversy over the meaning of *planet*, but a problematic pedagogy (Sykes, 2001). The public coming into the exhibit expected to see nine planets, and due to the ambiguous presentation of Pluto (as neither planet nor not-a-planet), the public left still thinking that Pluto was presented as a planet. Thus, the planetarium exhibit did not serve to educate the public regarding the fragile classification of Pluto as a planet, but rather only ruffled the feathers of the astronomers who saw the sloppiness behind what the exhibit was trying to do.

By displaying a classification system that rejected some scientific cosmologies and the dominant cultural cosmology, the planetarium exhibit limited the ease with which the term *planet* could be traded between scientists and the public. The response from those whose cosmologies had been erased was to argue for a return to the status quo by invoking the language of majority and minority; implying that, in some ways, science (or at least public display of science) ought to work like a democracy or a court of law in which one is innocent until proven guilty; a planet until proven otherwise. The Hayden Planetarium stood by its classification system, but shortly after this controversy installed a plaque and new kiosks to answer the visitor's most common question, 'Where's Pluto?' (Chang, 2001b). During this episode, unlike when the IAU formally defined *planet*, the trading zone did not completely dissolve because the astronomical community, with the help of disgruntled members of the public, was able to veto the AMNH's claim to authority.

Enter 2003 UB_{313}

In the previous sections, I discussed the relations between scientists and between scientists and their publics, using journal articles and the display at the Hayden Planetarium as a way to track the exchange between different epistemological communities. But there is another community to consider. Astronomy has a legacy of amateurs who actively engage in scientific discussions and even contribute to research. Amateurs, or science enthusiasts, contribute most to science through observation and collection. As a field of science becomes increasingly dependent on expensive equipment, the utility of amateurs becomes limited. But because astronomy has continued to depend on collection as a primary activity, amateurs have never been completely marginalized. Amateur astronomers also remain active because, contrary to many other fields in the physical sciences, professional astronomers never achieved complete monopoly of research (Rothenberg, 1981). Instead, during the professionalization of astronomy in the late Victorian period, amateurs became institutionalized (Lankford, 1981a, b). This legacy continues today as professional astronomers foster relationships with amateurs – relationships predicated on one-way flows of information. Professionals establish hegemonic arrangements: they make a data-gathering request and amateurs oblige. Amateur science becomes defined as collection and demarcated from the professional science of analysis and synthesis.[7]

One forum of exchange between amateurs and professionals is the Minor Planet Mailing List (MPML).[8] This email list, moderated by an amateur, represents an attempt to move from a one-way exchange of information towards a two-way dialogue. As such, the MPML can be considered a place of trading that extends exchange beyond the professional community, allowing amateurs to both provide and receive scientific data to and from professionals. Starting in April 2000, several hundred emails have been sent to this list per month, mostly discussing technical developments and discoveries in comet, asteroid, and Kuiper Belt research. In July 2005, a rapid sequence of emails was sent out announcing the discovery of large KBOs. These discoveries were the tipping point in Pluto's story, the moment when astronomers had to decide if Pluto might not be a planet but rather a KBO or if there were potentially dozens of new planets to add to the nine-planet model of the Solar System.

At 22.00 hours on 28 July, Spanish astronomer Jose-Luis Ortiz, emailed the MPML with 'important news' of the discovery of a TNO that might be comparable to or bigger than Pluto. Ortiz included coordinates and encouraged the list to take a look, 'This object is beyond Pluto and almost reachable by most amateurs, which is the reason why we write here!' (Ortiz, 2005). A little after midnight, the Minor Planet Center (MPC) assigned it the provisional designation of 2003 EL_{61} (Minor Planet Center, 2005a). At 01.53 hours, an astronomer messaged the MPML suggesting that 2003 EL_{61} was the same as an object unofficially named in an abstract from astronomer Mike Brown's research group at CalTech for a conference in the fall. This object, however, hadn't been officially registered with the MPC (Tholen, 2005a). Discussion of 2003 EL_{61} persisted on the MPML throughout the morning and afternoon of the 29 July . Topics ranged from who would receive credit for the discovery (ultimately Ortiz, because he was the first to report the coordinates to the MPC), to the pros and cons of releasing such data to the scientific community before official publication, to new data on the object made possible by the initial email sent by Ortiz. At one point, a congratulatory email was sent by an amateur astronomer naming Ortiz the first amateur to discover a minor planet (Yeung, 2005). This misconception (Ortiz is a professional astronomer in Spain) was soon corrected (Grav, 2005).

At 19.30 hours on 29 July, the MPC issued a circular announcing 2003 UB_{313} (Minor Planet Center, 2005b). At 20.00 hours, Ron Baalke, an amateur astronomer and NASA webmaster, emailed MPML excitedly, 'Forget 2003 EL_{61}, look at 2003 UB_{313}! 18.9 magnitude at 96 AU, and an H of –1.1!' (Baalke, 2005).[9] 2003 UB_{313}, discovered by Mike Brown and his team, was the second minor planet to be announced in 24 h whose initial data predicted it to be more massive than Pluto. This is surely no coincidence. However, to understand the events of 28 and 29 July, it is perhaps best to leave the real-time reporting of the MPML and consider a retrospective reconstruction.

Mike Brown et al. had knowledge of three large KBOs prior to 29 July (2003 UB_{313}, 2003 EL_{61} and 2005 FY_9 [Minor Planet Center, 2005c]). The

team decided to gamble and postpone official announcement and registration of the objects until a Division for Planetary Sciences meeting in September 2005. However, knowledge of Ortiz's announcement and awareness that the MPML community made the connection between 2003 EL_{61} and Brown's unnamed object in the abstract raised the team's hackles. A quick Google search produced data (telescope positions) that the team thought secret, or at least not easily found. Anyone looking for Brown's unnamed object could also see that Brown's team was looking at two additional objects. Although Brown lost discovery credit on one object, he refused to lose out on the other two – especially the large 2003 UB_{313}.[10] Thus, it was on 29 July, not in September, that these objects challenged Pluto's status within the professional and amateur astronomical community. An email thread to the MPML entitled '2003 EL_{61}, 2003 UB_{313}, Pluto & Planetary Status', which started on 30 July at 04.46 hours makes clear the immediate understanding by the astronomical community of the ramifications of these discoveries.

After the initial shock of these discoveries wore off, the topics of emails sent to MPML broadened and several authors wrote about the role of amateurs within the planetary science community. In these emails, the amateur was often willing to accept the professional's dominance. For example, when voicing a scientific opinion, amateurs book-ended it with an apology about their status: 'Please forgive me my amateurish description, I have only a very limited knowledge of celestial mechanics astrodynamics' (Raab, 2006).[11] Amateurs also drew attention to the fact that several discussion threads concerned professionals rather than themselves. A discussion about who should get credit for discoveries followed the Ortiz/Brown dispute. One amateur commented on this thread, 'Fascinating discussion we amateurs do not have to worry about at all. Being a discoverer translates just into a marginally better chance [for an amateur] to be funded' (Nemec, 2006).[12] Neither quote above fully indicates the amateur's feeling towards marginalization; however, the latter quote betrays frustration with barriers to funding (and the attending prestige) imposed by the amateur/professional hierarchy.

During a time of crisis or conflict, the distinction between professional and amateur sharpens as professionals assert their dominance in order to resolve the conflict in favor of professional goals (Lankford, 1981b). We can see this happening as questions about the definition of planet were discussed. Following the announcement of the three KBOs in late July, an amateur (albeit an amateur with a backyard observatory) prompted a discussion on the MPML regarding how these discoveries affect Pluto's planetary status. This provoked an irate response from a professional. The astronomer wrote:

> The issue has been raised [of whether Pluto should be downgraded to minor planet status], but it shouldn't [be], because there is no formal definition that divides major and minor planets. (Tholen, 2005b)

And the amateur responded: 'It seems to me that the reticence of scientists to accept a paradigm shift, while typical of the history of science, is only a delaying of the inevitable' (Crawford, 2005).

From here, the discussion devolved into bickering, with the amateur advocating that a distinction be made between minor and major planets and the professional denigrating this suggestion by saying that such a definition is useless, as it doesn't change how 'we' do science. Although this conversation is an exchange between one amateur and one professional, it signifies a move by professionals to redefine the arena of communication – the reach of the trading zone – to exclude amateur collaborators. As soon as questions are raised between communities regarding the term *planet*'s utility, it no longer serves the common parlance. The dialog provided a space for professionals to reassert their dominance over amateurs. As conversations about 'what is a planet' continued intermittently following the discovery of 2003 UB_{313}, professionals increasingly wrote in a technical language. *Planet* became a term less and less accessible to those without a strong astrophysics background. The increased complexity in language did the same work as an increased complexity of instrumentation – it served to limit accessibility of the field only to those with the proper material and educational resources.

The most significant consequence of the discovery of 2003 UB_{313} was that it needed a name. However, whether it was actually the 10th planet or another KBO would dictate the naming process. If the object was determined to be a KBO it would fall under the jurisdiction of the Minor Planet Center and, by their rules, the discoverer would get naming rights. If it were a planet, the IAU would oversee the naming process. Thus, the IAU would finally have to come up with a formal definition for *planet*. If the definition excluded UB_{313}, astronomers would be forced to revoke Pluto's planetary designation.

The IAU formed a committee to define *planet*. In light of the potential demotion of Pluto and its perceived public impact, the IAU appointed writers and historians of science, in addition to astronomers, to the Planet Definition Committee (Gingerich, 2007). The seven-member committee consisted of six trained astronomers, four of whom were also science writers, historians, or otherwise known for popularizing science, and one popular science writer without a scientific background.[13] According to a paper written by Owen Gingerich, chair of the Planet Definition Committee, their task was to 'craft a scientific, but culturally sensitive definition' (Gingerich, 2007: 139). The work of this committee brings Pluto's journey to the summer of 2006.

Planet Defined

The Planet Definition Committee was slated to present a definition of planet to the IAU membership at the triennial General Assembly (GA) in August 2006. The IAU's executive committee hoped that, by virtue of selecting a committee that included writers and science educators, as opposed to exclusively astronomers known for having strong views on Pluto's status (which was the presumed reason for a failed attempt at defining planet several years earlier), the definition would be well received at the

GA. The IAU executives expected that this committee would rise to the challenge of taking into account 'cultural and popular issues' and compose a definition that would sufficiently speak not only to professionals but also to 'everyone who is interested in the skies and planets' (Ekers, 2006). However, the convened astronomers intensely contested the language and meaning of the definition proposed by the Committee, which in essence defined planet as any round object orbiting a star. Over the 10 days of the conference, the definition committee had to facilitate an impromptu and iterative process to rewrite the definition, almost entirely abandoning the definition they proposed at the start of the GA. The final definition represented an attempt to reconcile the scientific priorities of structuralists and dynamicists. In the process of appeasing these two sub-disciplines, the 'culturally sensitive' objective of the definition was lost and the IAU stripped Pluto of its planethood. In defining planet, the IAU wielded its authority to impose an Aristotelian classification system on Solar System objects. The process of moving from a prototypical to Aristotelian system exposed and articulated the disunity between cosmologies. In making the contact language itself the focus of discourse, the trading zone dissolved.

The initial definition of planet, which used roundness as the demarcation criterion, included 12 planets in our Solar System: the canonical nine plus Ceres (located in the asteroid belt between Mars and Jupiter), 2003 UB_{313}, and Charon. This definition privileged structure (roundness) as the defining scientific characteristic of a planet. To justify this choice, Gingerich explained that the committee decided to let 'nature make the decision about what a planet is or not'. At the Plenary Session on 22 August, Gingerich further explained that while the committee was asked to consider cultural and historical issues, the members knew that regardless of scientific grounding, Pluto would be affected. 'Accidentally, by choosing roundness as a criterion, Pluto would remain a planet, but that was not an essential step in our negotiations. It was rather the science for it' (Gingerich, 2006). There are several interesting elements in Gingerich's statement. First, he establishes that despite the IAU's intent to take into account public reaction, the committee claimed to use science and physical nature as the basis for the definition. Consequently, Gingerich argues that Pluto remained a planet *not* because the committee was worried about cultural sensitivity, but because 'nature' decided by 'accident'. In essence, the definition committee invoked the authority of science/nature in a move that tried to deny the social influence of scientific practice (with a resulting happy 'accident' that the cultural cosmology prevailed). The purported cultural and historical work of the committee was limited to proposing a new nomenclature: the word 'pluton' to define a new class of planetary objects.

The assembled IAU members did not greet the proposed definition with enthusiasm. The most vocal critique targeted the absence of dynamic science in the definition. On 18 August, astronomers unaffiliated with the Definition Committee presented a revised definition (one that first and foremost defined planet to be 'the largest object in its population' and secondarily round)

to approximately 100 members at a conference session held by the IAU Division III (Planetary Systems Sciences). To address the demands of the dynamics community, the Definition Committee revised its definition to include language from the Division III proposal. However, dynamics was again removed from prominence and placed in a secondary clause to distinguish a 'classical planet' as the dominant object in its local population from a 'dwarf planet', which is not the dominant object.

This new resolution was introduced at the Plenary Session on 22 August, during which comments were solicited from the audience. The audience voiced displeasure with this revised definition. The dynamics community still did not like the fact that structure was being favored, especially because the Definition Committee members continued to emphasize the physical composition of the planets in their speeches. The comments from the audience quickly escalated to anger. In an attempt to regain control of the meeting, the Committee suggested moving beyond Resolution 5 (the bulk of the definition). A voice from the audience proclaimed 'Let the people speak', which provoked loud applause from the crowd. Several subsets of planetary scientists (extrasolar planetary astronomers as well as dynamicists) did not feel that the definition addressed the needs of their disciplines. In addition, they were frustrated that the Definition Committee did not seem to want to take into account the 'people's' (astronomers not on the Committee) voice.

In response to the dissatisfaction of the professional community, the Definition Committee agreed to meet informally with interested parties on the evening of the 22nd to continue the discussion in a more constructive manner. The result of this informal meeting was that three categories of objects orbiting the Sun[14] needed to be defined: planets, dwarf planets, and small solar system bodies (Anonymous, 2006a). The empirical distinction (structural and dynamic) between these objects became Resolution 5A. Resolution 5B would immediately amend 5A to change 'planet' to 'classical planet', thus changing the meaning of 5A to establish a category of planets, of which classical and dwarf are subgroups. Thus, approval of 5A would establish eight planets while the additional approval of 5B would immediately contradict and trump 5A to establish 12 planets. Put another way, 5A unites two scientific cosmologies and 5B preserves the cultural cosmology of Pluto as a planet.

At the closing session on 24 August, astronomers still in attendance received a final chance to express opinions about the *planet* resolutions. Audience members reintroduced several criticisms, such as the confusion of 'dwarf planet' not being a planet, the failure to propose a definition that would be suitable for extrasolar planets (planets orbiting other stars), and the extent to which scientific language (hydrostatic equilibrium) should be preferred over publicly accessible language (nearly round). At the end of a fruitless exchange between audience members and the resolution committee, a (non-planetary) astronomer summed up the feeling of the professional community as well as what should be done. 'Like many people, I have been very unhappy with the process', he began. However, as the conference progressed, the Definition Committee became increasingly responsive and proposed a

'sensible, acceptable, streamlined, much simplified' definition. The astronomer continued to stress that it was most important for the community to:

> come away with a positive resolution because it would be disastrous for astronomy if we come away from the General Assembly with nothing. We will be regarded as complete idiots .... [It is] important that we overwhelmingly support this motion. (Anonymous, 2006b)

He went on to emphasize that not only should the definition be approved, but that members also should express the positive implications of this definition to the public and media: the definition of a planet can be thought of in more than one way (dynamic versus structural), we have learned new things, and new objects are continually being discovered. He concluded that everyone in the room must 'support this motion overwhelmingly, and then we have to go away and sell it in a very positive way … the fact that Pluto is being demoted is not so important'. The loudest applause at the session accompanied him back to his seat. With that, the 420 members still in attendance (four % of the total IAU membership) voted with a clear majority in favor of Resolution 5A.

The meeting then moved on to the more culturally sensitive resolution, 5B. As the moderator ironically put it, '5B involves inserting one word. Surely not a serious matter.' To illustrate what the addition of 'classical' would do, the moderator visually showed a balloon to represent 'planets', a box of cereal (a pun on the asteroid Ceres) and a stuffed Disney Pluto to represent 'dwarf planets', and a lemon for the 'small solar system objects'. These categories remain distinct in 5A. However 5B's introduction of 'classical' makes an umbrella category of *planet* (here the moderator opens an umbrella with a banner reading 'Planets' hanging off it and brings the balloon, box of cereal, and Disney Pluto underneath it). To emphasize the significance of this grouping, the moderator held up the stuffed Pluto next to the word planet and said, 'And if we do this, then *that* pertains' (see Fig. 2). If the Assembly were to approve 5B, both *classical planets* and *dwarf planets* would be *planets* and Pluto would not have to be reclassified.

However, members present asserted their authority and voted against 5B (three-quarters of the audience voted negatively). Thus, the approved definition largely reflects scientific priorities, devoid of the cultural or historical meaning the Definition Committee was charged to, and had worked hard to, provide.

The IAU membership left Prague having approved the following statement:

> The IAU therefore resolves that planets and other bodies in our Solar System, except satellites, be defined into three distinct categories in the following way:
>
> (1) A 'planet'[1] is a celestial body that: (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.

FIGURE 2
' ... then *that* pertains'

Source: IAU Webcast.

(2) A 'dwarf planet' is a celestial body that: (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,[2] (c) has not cleared the neighborhood around its orbit, and (d) is not a satellite.

(3) All other objects[3] except satellites orbiting the Sun shall be referred to collectively as 'Small Solar System Bodies'.

Footnotes:

[1]The eight planets are: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.

[2]An IAU process will be established to assign borderline objects into either 'dwarf planet' and other categories.

[3]These currently include most of the Solar System asteroids, most Trans-Neptunian Objects (TNOs), comets, and other small bodies. (International Astronomical Union, 2006)

Competing cosmologies (scientific and cultural) shaped the debate over the definition of planet. *Planet* means different things in different contexts, which is why, left undefined, it served as part of a contact language between groups. It means something material to structuralists and relates to movement for dynamicists. In this Aristotelian, binary system, part (b) accounts for the structural cosmology and (c) for the dynamic cosmology. Part (a), in contrast, completely excludes a sub-discipline (extrasolar planetary

astronomers) from the discourse. In addition, the defeat of Resolution 5B, by demoting Pluto, rejected the cultural cosmology of nine planets. The boundaries of the trading zone were redrawn to exclude participants and the contact language acquired a homogenous, global meaning due to a shift from prototype to Aristotelian classification. The definitional flexibility upon which the cooperation within trading zones depends was erased.

The Executive Committee of the IAU and the Definition Committee had one more chance to preserve some of the cultural cosmology regarding Pluto. Though no longer a planet, perhaps there was still room for astronomers to acknowledge the significance Pluto has for the general public. In that vein, the moderator referred once again to her Solar System proxies, this time singling out the box of cereal and the Pluto stuffed animal. The purpose of Resolution 6, she explained, was to distinguish between these two objects. Richard Binzel formally explained that Resolution 6A recognizes that the dwarf planet Pluto is the prototype of a new category of objects orbiting beyond Neptune. Resolution 6B named this category 'Plutonians', in honor of Pluto's place in astronomical history. Audience members raised similar points in response to Resolution 6A as they did to Resolution 5A. Notably, one astronomer asked if the new category described planets of similar size to Pluto or those that moved like Pluto. Binzel responded that the new category included all dwarf planets (as defined in Resolution 5B) that were also located beyond Neptune. Later, another commentator pleaded that the IAU not involve itself in the nomenclature of sub-categories. This would be the first official category for trans-Neptunian objects, interfering with the flexible taxonomy astronomers have been using for decades to characterize these objects. Ultimately, Resolution 6A was approved by a small majority, acknowledging that Pluto deserves an elevated place in astronomical taxonomy. Resolution 6B, coining the category 'Plutonian', failed to garner a majority of the votes, signaling resistance in the community to a name insufficiently distinct from unofficial categories such as plutinos.

Following the conference, dwarf planet 2003 UB_{313} was finally ready to receive an official name. Since dwarf planets are minor planets, the Minor Planet Center allowed discoverer Brown to name the object. Brown chose Eris, the goddess of strife and discord, as a fitting moniker for this controversial member of the Solar System.[15]

Plutoed

Defining *planet* concretized a classification system and made explicit disagreements in the discourse. When considering the disunity of science, scholars make the counterintuitive observation that 'the disunified, heterogeneous assemblage of the subcultures of science is precisely what structures its strength and coherence' (Galison, 1996: 13; see also Dupré, 1993). However, this case study shows that the stability inherent in disunity breaks apart when differences are exposed and forced into artificial consensus. The process of articulating a single definition of planet brought to light several competing cosmologies and prioritized some over others. When *planet* lost its flexibility, the trading zone in which it was exchanged

was also disrupted. How was discourse reshaped after the IAU GA and how did actors navigate through the instability? This section begins by looking at reactions of those who approved of the new definition.

Unsurprisingly, two people who came out in support for the IAU definition were Tyson and Marsden, mentioned in this paper as early promoters of Pluto's demotion. In 2006, Pluto finally came under Marsden's jurisdiction as director of the Minor Planet Center. Marsden ceremoniously assigned Pluto the Minor Planet number of 134340. Tyson was finally able to say that his planetarium display accurately reflected the current thinking of planetary scientists. Pluto never was, and now never will be, a planet at the renovated Hayden Planetarium.

Marsden and Tyson have consistently cited scientific reasons, to the exclusion of cultural expectations, to justify their classification of Pluto. Right before the IAU GA, Marsden wrote an Op-Ed piece for *The Guardian*, criticizing 'not only schoolchildren brought up on Disney cartoons but even some astronomers who should know better [than to] wax sentimental over Pluto's special place .... It makes no scientific sense to have nine or 10 [planets]' (Marsden, 2006). Culture, not Pluto, needed demoting.

Tyson took this argument a step further when, speaking to Mark Sykes and a public audience at 'The Great Planet Debate' on 14 August 2008, he insisted that the word *planet* has lost all scientific value. *Planet*, with its inherent vagueness, had utility when we didn't know much about the planets. Now that our knowledge has deepened, a new system I needed to reflect scientific achievements. The attempt to force a single understanding of *planet* back onto heterogeneous astronomical discourse would only cause strife.

Sykes, Tyson's opponent in this debate (a reprise of the conversation that appeared in the *New York Times* in 2001), is a proponent of Pluto the Planet. Sykes maintains that roundness should be the sole criterion for the definition of planet. He rejects the IAU definition and ignores the dynamics community. The discomfort he feels stems from the failure of the definition to supply a classification system that reflects how scientists think, which for Sykes is through the grouping of similar objects. Both Tyson and Sykes reject the Aristotelian classification system, but for different reasons.

The astronomer who perhaps had the most at stake in Pluto's status was Stern. Stern is the Principal Investigator of New Horizons, the first mission to Pluto and the Kuiper Belt. From its inception, the rhetoric surrounding New Horizons capitalized on the mystique of unlocking 'one of the solar system's last, great planetary secrets'.[16] After the demotion, the following bitter message headlined NASA's New Horizons website:

> Poor New Horizons. When it launched in January 2006 it was with all the prestige of the first spacecraft to study Pluto, the last unvisited planet in the solar system. That changed seven months later, when astronomers decided that Pluto was not a planet. For the time being, New Horizons is at least the first mission to a dwarf planet – the new class of objects into which scientists dumped Pluto … Charon had been generally regarded as Pluto's moon, but the new definition of planet may change its status as well. Apparently, not even the astronomers are entirely sure.[17]

This text primarily attributes Pluto's demotion to scientists, not to natural order. Further, describing how scientists 'dumped Pluto' into a new category undermines any elegance or rationale that might have been involved in the process. On the Jet Propulsion Laboratory's New Horizons site, Stern's PI Perspective column on 6 September 2006, 'Unabashedly Onward to the Ninth Planet', flat out refused the IAU's demotion. Citing the IAU definition as sloppy and contradictory, 'The New Horizons project, like a growing number of the public, and many hundreds if not thousands of professional research astronomers and planetary scientists, will not recognize the IAU's planet definition.' Stern (2006) argued that the increasing number of dwarf planets is akin to a paradigm shift that forces astronomers to recognize that Earth is the true misfit in the Solar System, not Pluto. Others astronomers, he wrote, responded to this challenge with discomfort, and in an effort to maintain an established order, rejected instead of embraced the plethora of icy Pluto brethren (Stern, 2006).

Can Stern's accusation not be turned on himself? Is he not the one resisting a new order? One aspect of the new definition of planet is that it effectively closes the Solar System's frontier, leaving no possibility for discovering a new planet. The name of the mission, New Horizons, builds on favored rhetoric in the American space program, which emphasizes that exploring space is a continuation of manifest destiny. Boosters of manned missions to Mars invoke Turner's frontier thesis, arguing that exploration is necessary for the health of the American soul (Zubrin, 1996; see also Limerick, 1992 for a critique of the analogy between space and the western frontier). By rejecting the definition of planet, Stern advocates an open frontier, allowing for the possible discovery of new planets – new worlds – in our Solar System. This keeps the activity of exploration exciting and not just a matter of banal reconnaissance. Stern, in fighting to keep his mission publicly interesting, helps us see the real cosmological stakes of Pluto's demotion: a closed frontier.

Epilogue

Throughout this story, astronomers claimed that people, specifically school children, cared about Pluto's fate. Following demotion, evidence of concern for Pluto abounded in professional and lay media. There was an air of humor in the hundreds of Op-Ed pieces, online petitions, T-shirt designs, political cartoons, late night TV satires, bumper stickers, YouTube videos, and web comics that mulled over Pluto's change in status. Some of the Pluto humor, like the astronomers' reactions, arises from a feeling of discomfort – a discomfort stemming from awareness that science is not as robust and objectively true as elementary education teaches. Pluto's demotion exposed the role that scientists and scientific institutions play in constructing science. In one cartoon an astronomer drags Disney's Pluto to an execution room, in another an astronomer points to a chart that has a picture of the dwarf planet Pluto and reads 'not a planet' and another chart that has a picture of actor Tom Cruise jumping on a couch and reads 'not a star'. In both of these comics, demoting Pluto is made to appear arbitrary, not scientific.

These cartoons reflect how, as has been true since its discovery, Pluto is a scientific *and* cultural object. For most of the 20th century this dual identity was not a source of controversy because trading zones facilitated communication among astronomers, amateurs, educators, and enthusiasts. When the IAU forced a rigid Aristotelian classification system on the Solar System, Pluto was deprived of its multiple identities. The attempt to mask the heterogeneity of planetary science with a homogenous definition of planet produced instability resulting in the emergence of a discursive space in which the authority of astronomers could be questioned. Non-scientific institutions began to issue their own pronouncements about Pluto's fate. In the most extreme case, the State of New Mexico declared that Pluto is still a planet. On 13 March 2007 the 48th legislature of New Mexico passed this joint memorial:

> NOW, THEREFORE, BE IT RESOLVED BY THE LEGISLATURE OF THE STATE OF NEW MEXICO that, as Pluto passes overhead through New Mexico's excellent night skies, it be declared a planet and that March 13, 2007 be declared 'Pluto Planet Day' at the legislature. (House Joint Memorial 54, 2007)

Library books that refer to Pluto as a planet have placards affixed on the front page to let the reader know that the book contains out of date information. Children and adults are still trying to figure out whether or not a dwarf planet is or is not a kind of planet. Most astronomers are returning to their daily tasks, unaffected by the change of Pluto's status, and just trying to move beyond the debate. Pluto continues to orbit the Sun with its icy brethren, oblivious to its terrestrial significance.

Notes

The idea for this paper began as an assignment for Sheila Jasanoff's graduate seminar, 'Science, Power, and Politics', taught at the Harvard Kennedy School. The early guidance provided by Professor Jasanoff and students in this class forced me to consider what was really at stake in this debate. My teachers and colleagues in MIT's Program in History, Anthropology, and Science, Technology and Society encouraged me to continue working on this quirky moment in the history of science. Stefan Helmreich and David Mindell read countless drafts of this paper, suggesting ways to strengthen my analysis and language. Meg Jacobs, Vincent Lépinay, Anne McCants, Susan Silbey, Etienne Benson, Nick Buchanan, Michael Rossi, and Rebecca Woods helped me clarify the central story. Finally, I would like to thank Michael Lynch for his careful editing and the comments of two anonymous readers who helped to give this work a final polish.

1. Though I do not explicitly engage with Thomas Gieryn's (1999) boundary work framework, at many points during the story there is clear evidence of astronomers (and lay participants) negotiating the social boundary between science and non-science in order to gain authority and resolve the debate over Pluto's status in their preferred direction.
2. I use contact language in a more limited sense than Galison. He extends the language of exchange to include structured symbolic systems (Galison, 1997: 835).
3. Tombaugh describes himself as an amateur astronomer when he began his work at Lowell Observatory. He rationalizes that the Observatory hired an amateur to carry out the planetary hunt because hiring a professional to do a task whose success was unlikely would have been too great a cost (Tombaugh, 1980).

4. Name suggestions printed in *New York Times* articles and editorials from 15 March to 1 May 1930 include: Atlas, Prometheus, Tempus, Minerva, Vergilius, Erebus, Leda, Pluto, Icarus, Vulcan, Radiolanus, and Cronus or Kronus.
5. Evidence of this association is seen in the political cartoons and web comics produced after Pluto's demotion. Dozens of these use Pluto the Pup to represent the planet or create visual juxtapositions between the planet and the pup.
6. One astronomical unit is the distance between the Sun and Earth. Shortly after the publication of Stern's paper, this region was renamed the Kuiper Belt and confined to 30–50 AU.
7. There are several Internet sites on which a research group states the area of the sky they are studying and amateurs are able to upload observational data to a searchable database. One example is the Universidad del Paas Vasco's Planetary Virtual Observatory & Laboratory (PVOL): <www.pvol.ehu.es>.
8. The MPML is a Yahoo Group 'populated with many of the world's best amateur astronomers as well as many professional astronomers … since many active MPML members are seriously involved in this field of research, the posts to this list can often be rather technical' (Kowalski, 2008).
9. The magnitude, AU and H are all indications that the object is comparable to Pluto in size.
10. In the month following, Brown made several accusations of fraud and computer hacking toward unknown astronomers and toward Ortiz. This incident raises many questions about data disclosure on the Internet, ethics of accessing this data, and credit of discovery (see Wilkinson, 2006).
11. I reference this email with a sense of irony, as even knowing the field of 'celestial mechanics astrodynamics' exists indicates the sophistication of the amateurs on the MPML.
12. This comment is also incorrect given Tombaugh's amateur status when he discovered Pluto.
13. Committee members were Andre Brahic, Iwan Williams, Junichi Watanabe, Richard Binzel, Catherine Cesarsky, Dava Sobel, and Owen Gingerich.
14. Note that at this point the definition has shifted from a general definition of planet to one only relevant to this Solar System.
15. In 2008, the International Astronomical Union announced that dwarf planets that are also trans-Neptunian are to be called Plutoids. There are currently four plutoids in the Solar System, including Pluto and Eris.
16. This text appeared on NASA's New Horizons mission page between 26 November 2005 and 29 August 2006. Available at <www.nasa.gov/mission_pages/newhorizons/main/index.html> accessed via Internet Archive <www.archive.org>.
17. This text was on the previous cited website from 29 August 2006 to 28 October 2006.

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