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Terminology, Stars and (Exo)Planets

Abstract

This contribution examines the formation, evolution and use of terms in astronomy. The term *planet* is discussed in detail through the analysis of specialized contemporary sources, with focus on how the discoveries of Neptune, Uranus and Pluto changed the meaning of *planet*. Consideration is also given to other bodies originally classified as planets, illustrating a repeating pattern of scientific advancement blurring the boundaries of what *planet* denotes before linguistic and terminological usage adapts to reflect scientific understanding. Further consideration is given to the qualifier *dwarf* in denoting bodies both too small and too large to be classified as planets, which constitutes a modern blurring of the lines of planethood in the field of exoplanetology. Through the analysis of three leading astronomical journals, it is shown that despite the lack of a centralised authority actively regulating terminology, the prototype term *Hot Jupiter* has engendered new series of terms using differing terminological and conceptual regimes to prioritize different characteristics of exoplanets, allowing for efficient communication in specialised and general discourse.

Keywords: terminology, lexicography, terminological variation, astronomy, exoplanets, LSP

Introduction

The etymology of the word *planet* as a *wanderer*, or *wandering star*, is reflected in its original definition in the *Oxford English Dictionary* (OED): "Each of the seven major celestial objects visible from the earth which move independently of the fixed stars," which distinguishes planets from the two other types of celestial bodies known to the ancient world: the fixed stars and the comets, inheriting their name from the Greek *ἀστὴρ κομήτης*, 'long-haired star' (OED), evoking their characteristic tails. This division between stars, planets and comets is apparent in English dictionaries as early as Philipps' 1663 *New World of English Words*, where *planet* is defined as "A Wandering Star, of which there are seven that take their Names from the chief Heathen Deities, viz. Saturn, Jupiter, Mars, Sol, Venus, Mercury, Luna." From a modern perspective, this definition is problematic, as it classifies vastly different bodies in a single category, which undermines predictive and explanatory power of the logic governing the categorisation. With the advent of heliocentrism, the definition of *planet* changed to fit scientific theory, as can be seen in Blount's 1707

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Glossographia where the definition of *planet* reflects the inherited idea of planets moving: "the Erratick or Wandring Stars which are not, like the fixed ones, always in the same Position to one another" while also providing an early attestation of the distinction between primary and secondary planets: "Of these are 6 Primary ones, Mercury, Venus, the Earth, Mars, Jupiter and Saturn; and 10 Secondary ones, […] the Moon, the 4 Satellits of Jupiter, and the five belonging to Saturn" [sic]. By the time of the 1785 6th Edition of Johnson's *Dictionary*, the definition of *planet* still made reference to its etymology, but the use of the terms *primary planet* and *secondary planet*[1] was further entrenched:

> Planets are the erratick or wandering stars, and which are not like the fixt ones always in the same position to one another: we now number the earth among the primary planets, because we know it moves round the Sun, as Saturn, Jupiter, Mars, Venus, and Mercury do, and that in a path or circle between Mars and Venus: and the moon is accounted for among the secondary planets or satellites of the primary, since she moves round the earth.

Planet or comet?

A clear hierarchy had emerged: stars, comets and the planets known since pre-history, orbited by newly discovered moons. This established order was challenged by scientific progress with Sir William Herschel's 1781 discovery of "A curious either Nebulous star or perhaps a comet" (Herschel in Schaffer 1981: 12). Although he wrote that: "My surmises were well-founded, this proving to be the Comet we have lately observed" (Herschel 1781: 492), Herschel also noted "The comet appeared […] without the least appearance of any beard or tail" (1781: 498). Doubts about what to call Herschel's discovery were also reflected in his correspondence with the Astronomer Royal, Nevil Maskelyne, acknowledging "I don't know what to call it. It is as likely to be a regular planet […] as a Comet …" (Maskelyne in Dick 2013: 44).

The terminology Herschel used in his early writings about these observations reflect the evolving understanding of this particular celestial object. In his 1781 announcement of his discovery (Herschel 1781), *comet* is used 34 times to refer to his discovery, with the terms *fixed stars* and *planets* used to illustrate the differences between the newly discovered body and the established types of celestial object. Herschel also quotes his correspondence from Messier, who, after his own observations, also referred to the body as a *star,* a *comet* but not a *planet* (Messier in Herschel 1781: 500). It seems quite reasonable that these astronomers were reluctant to assert, on the basis of a small number of observations, that a new planet had been discovered, as no one had ever discovered a new planet.

Only after more than a year of further observations was Herschel confident of changing the term used to denote his discovery: "It appears that the new star, which I had the honour of pointing out […] in March 1781, is a Primary Planet of our Solar System." (Herschel 1783a: 1). At this point, the terminology he uses shifts to reflect this. Even though he recommends the name *Georgium Sidus* (1783a: 2) in deference to King George III of Great Britain, he only uses this proper name in 22 of the 95 cases (23%) when he refers to Uranus in his writings of 1783(a, b), 1787 and 1788; in two further cases, *the Georgium Sidus* is elided to *the Sidus* (2%). Other terms Herschel uses are *Georgian planet* (14 of 95 occurrences, or 15%), the term *primary planet* is elided to *primary* once (1%), but the bulk of references use the simplex term *planet* (56 of 95 cases, 59%). Overall, Herschel thus uses *planet* as either a simplex or part of a complex

1 Both first attested in 1664 (OED).

in 71 of 95 cases and would definitively anchor Uranus among the planets when he showed it to be much larger than Earth and to have its own moons (1783b, 1787, 1788).

"A Middle Rank"

With astronomers pointing evermore powerful telescopes skywards, the discoveries between 1801 and 1807 of Ceres, Pallas, Juno and Vesta between the orbits of Mars and Jupiter led to the family of primary planets swelling to 11, with the pace of discovery bringing into question the usefulness of the term *planet* if its members became so numerous so quickly. Significant terminological variation can be seen in Herschel's writings on Ceres and Pallas in 1802, referring to *The moving star discovered by Mr Piazza* (1802: 213), *Mr Piazza's star* (1802: 214), *Dr Olbers' star* (1802: 216). He also uses the names *Ceres* and *Pallas* and the generic "star", "curious object" and "celestial body" before an explicit appeal to the established hierarchy of celestial bodies to try and classify these new discoveries: "What are these new stars, are they planets or are they comets?" (1802: 223).

Herschel lays out definitions for planets on the basis of the known properties of the primary planets (1802: 224) and comets (1802: 226), making reference to size, orbital inclination, orbital eccentricity, the presence of satellites, atmosphere and separation. Given that Ceres and Pallas met neither the criteria for planethood nor comethood (just like Juno and Vesta would in 1804 and 1807 respectively), Herschel proposed a new class of celestial object according to these observable properties and provides an explanation of the term he proposed: "From this, their asteroidical appearance, if I may use that expression, therefore, I shall take my name, and call them *Asteroids*. These bodies shall hold a middle rank, between the two species that were known before" (1802: 228–9, original emphasis). Even though based on objectively verifiable astronomical observations, Herschel's creation of this "middle rank" of celestial bodies was not universally accepted, as Webster's 1828 *Dictionary* shows, with the definition of *planet* noting that "Four smaller planets, denominated by some, asteroids, namely Ceres, Pallas, Juno and Vesta, have been discovered between the orbits of Mars and Jupiter," (original emphasis) and *asteroid* being defined as "A name given by Herschel to the newly discovered planets between the orbits of Mars and Jupiter". The OED dates the competing term *minor planet* to 1823, defined as "An asteroid; (originally) spec. each of the four largest and earliest known asteroids, Ceres, Pallas, Juno, and Vesta." This terminological variation between *asteroid* and *minor planet* persisted in multiple languages, with the journal *Astronomische Nachrichten* publishing tables of data on *Kleine Planeten* from the 1850s until the 1980s, and the International Astronomical Union (IAU) including both the English *minor planets* and the French *petites planètes* in the full name of its Commission 20 from 1925 (IAU 2015; Folkner *et al.* 2018: 1).

With continued scientific progress as well as increasing levels of literacy and education, it is possible to see that until the 1830s, 11 primary planets were recognised beyond the specialised discourse of astronomers: works such as Vince's *A Complete System of Astronomy* (1823: 440), *First Steps to Astronomy and Geography* (1828: 71–2) and Olmsted's *An Introduction to Astronomy* (1830: 170) all agreeing what there were 11 planets: Mercury, Venus, Earth, Mars, Vesta, Juno, Ceres, Pallas, Jupiter, Saturn, and Uranus. The influence of scientific progress on non-specialised use of the term *planet* continued to blur the lines of planethood when John Herschel's 1849 *Outlines of Astronomy* listed 16 planets, adding Astræa, Heba, Iris, Flora and Metis, discovered between 1845 and 1848 (1849: 275) before the second edition of Mitchell's *Primary Geography* (1849: 169) compounded the problem of just what a planet was by naming the same 11 planets as the first edition (1843: 169), but excluding the five discoveries of 1845–1848. Both editions did however include the distinction between primary and secondary planets in this text destined for children, underlining the spread of this use beyond specialised discourse between astronomers. Scientific progress was yet again bringing about the problem of classifying dissimilar things into a single group, reducing the predictive and explanatory powers careful classification can afford. *Planet* was also becoming problematic in less-specialised circles: while learning the names of eight or nine planets is certainly feasible, the discovery of innumerable bodies in the asteroid belt meant these bodies could not all be planets before the term lost all usefulness to both astronomers and the general public.

Uranus, Neptune and Pluto

When Neptune was finally discovered in 1846 by Le Verrier, his terminology is fixed, referring to Neptune uniformly as a *planète*, given that Neptune's predicted size and mass made it far larger than Earth (Le Verrier 1846a–c), and upon observing Neptune, Galle agreed that it was indeed a planet, writing to Le Verrier that "The planet of which you indicated the position really exists […] I found a star of the eighth order […] observation of the following day showed it to be the searched-for planet"[2] (Galle to Le Verrier, Letter of 25 September, in Arago (1846: 659), original emphasis). Given its size, heliocentric orbit, very low orbital eccentricity and the subsequent discovery of its moons, it was clear than a new planet had been discovered, Neptune.

Upon further analysis of the positions of Uranus and Neptune, discrepancies between observation and gravitational theory's predictions (Crommelin 1931: 380), led to the hunt for the cause, with the mass necessary to produce the discrepancies indicating the presence of an undiscovered planet beyond Neptune (Mitton 2007: 273, 203–4). After Tombaugh made his observations at the Lowell Observatory, the observatory's director, V.M. Slipher, sent a brief announcement to the astronomical community (1930a: 1), using the terms *TransNeptunian Planet* and *Trans-Neptunian body* to denote the discovery. In a more detailed message the following day, the terms *planet, exterior planet, disturbing planet* and *external planet* were all used, before Slipher concluded that "This then appears to be a Trans-Neptunian, non-cometary, non-asteroidal body" (Slipher 1930b: 284) before also referring to "This remarkable Trans-Neptunian planetary body […] there appears present justification for referring to it as [Lowell's] Planet X" (Slipher 1930b: 284).

There was initially great uncertainty about Pluto's mass, with estimates ranging between one third and several times that of Earth (Crommelin 1931: 384–5), but since it orbited the Sun and not another planet, and as the mass range made Pluto larger than either Mars or Mercury (Dessler & Russell 1980: 690), it seemed entirely correct to call Pluto a planet. However, Pluto's mass has been reassessed (Dessler & Russell 1980: 690; Dick 2013: 17) and the perturbations in Uranus' and Neptune's orbits shown to be inaccurate (Standish 1980: 2005), to the extent that the currently accepted mass of Pluto is 1/459 that of the Earth (JPL 2021). Yet Pluto remained, somewhat uncomfortably, in the class of planets while Ceres, Pallas, Juno, Vesta and the bodies of the asteroid belt downgraded to *asteroids*. The discovery of Eris, both more distant and more massive than Pluto, implied that if Pluto was a planet, then so was Eris, as well as any other body bigger than Pluto orbiting the Sun. When added to the discovery of

2 Our translation. "La planète dont vous avez signalé la position, existe réellement. […] je trouvai une étoile de huitième grandeur […] observation du jour suivant décida que c'était la planète cherchée." [sic. original emphasis].

vast numbers of Kuiper Belt objects orbiting beyond Neptune, the accepted meaning of the term *planet* grouped together vastly different types of body, and was behind the IAU's 2006 Resolution B5, according to which *(1) A '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, and (c) has cleared the neighbourhood around its orbit,* while creating the new category: "dwarf planet" which meets requirements a) and b) of the above definition but which "*(c) has* not *cleared the neighbourhood around its orbit, and (d) is not a satellite*" (IAU 2006). There is thus a long history of the meaning of *planet* undergoing change, which continues with challenges to the IAU's definition of planet (Gaudin 2015; Dick 2013: 27–8; Hogan 2006: 965), but the motivation of the term *dwarf planet* is further hindered by the use of *dwarf* in several areas of astronomy.

Astronomy and *dwarf*

Per the IAU's definition, *dwarf* is used to qualify planets, but as Dick (2013: 10) notes: "In a linguistic contradiction truly to be regretted, a dwarf planet was ruled not to be a planet" but this is not without precedent, as dwarf novæ are not merely small novæ. These contradictions contrast with the common-sense interpretation that a *dwarf X* is a smaller version of X, such as *dwarf galaxy*. Furthermore, *dwarf* is also used as a modifier in stellar astronomy since at least 1914 with Russell (287) perpetuating Hertzsprung's use of *dwarf* and *giant* to denote two groups of stars on the Hertzsprung-Russell (HR) diagram.

On the HR diagram (see Figure 1), which plots start by their temperature (X-axis, decreasing from left to right) and luminosity (Y-axis, increasing bottom to top), *dwarf* denotes the stars that form a diagonal line from the top left to the bottom right and *giants* denoting stars in a separate group above and to the right of this diagonal. While the opposition between *giant* and *dwarf* reflects the usage of these qualifiers in general discourse (contrary to planets and novae but not galaxies), the subsequent discovery of white dwarfs created a further potential source of confusion, as white dwarfs form a distinct group on an HR diagram, sitting below and to the left of dwarfs, as they are neither dwarfs nor giants.

The ways in which *dwarf* is used in astronomical terminology has also been challenged with the discovery of brown dwarfs, subdwarfs, sub-brown dwarfs, L, M and T dwarfs, which appear in the extreme bottom right-hand corner of an HR diagram (Dick 2013: 111–113), forming another distinct group of bodies denoted using *dwarf* which are not dwarfs in Russell's sense. Further confounding the clarity of *dwarf* is the question of whether these recently discovered bodies are actually stars, due to their low mass and luminosity and the technicalities of fusion (Spiegel, Burrow & Milsom 2011; Dick 2013: 109–114). Whilst originally proposed as the defining characteristic of stars, not all bodies have the requisite mass and density for all the stages of the process of fusing hydrogen into helium, some able to host only the steps of deuterium fusion and lithium fusion rather than the whole process (Dick 2013: 113). As a consequence, the once clear boundary between planets and non-planets has become blurred on the higher end of the mass spectrum, just as it is blurred on the lower end of the mass spectrum with, unhelpfully for clarity's sake, the qualifier *dwarf* being used at both ends of the scale of planetary mass as well as for several types of stars and stellar remnants.

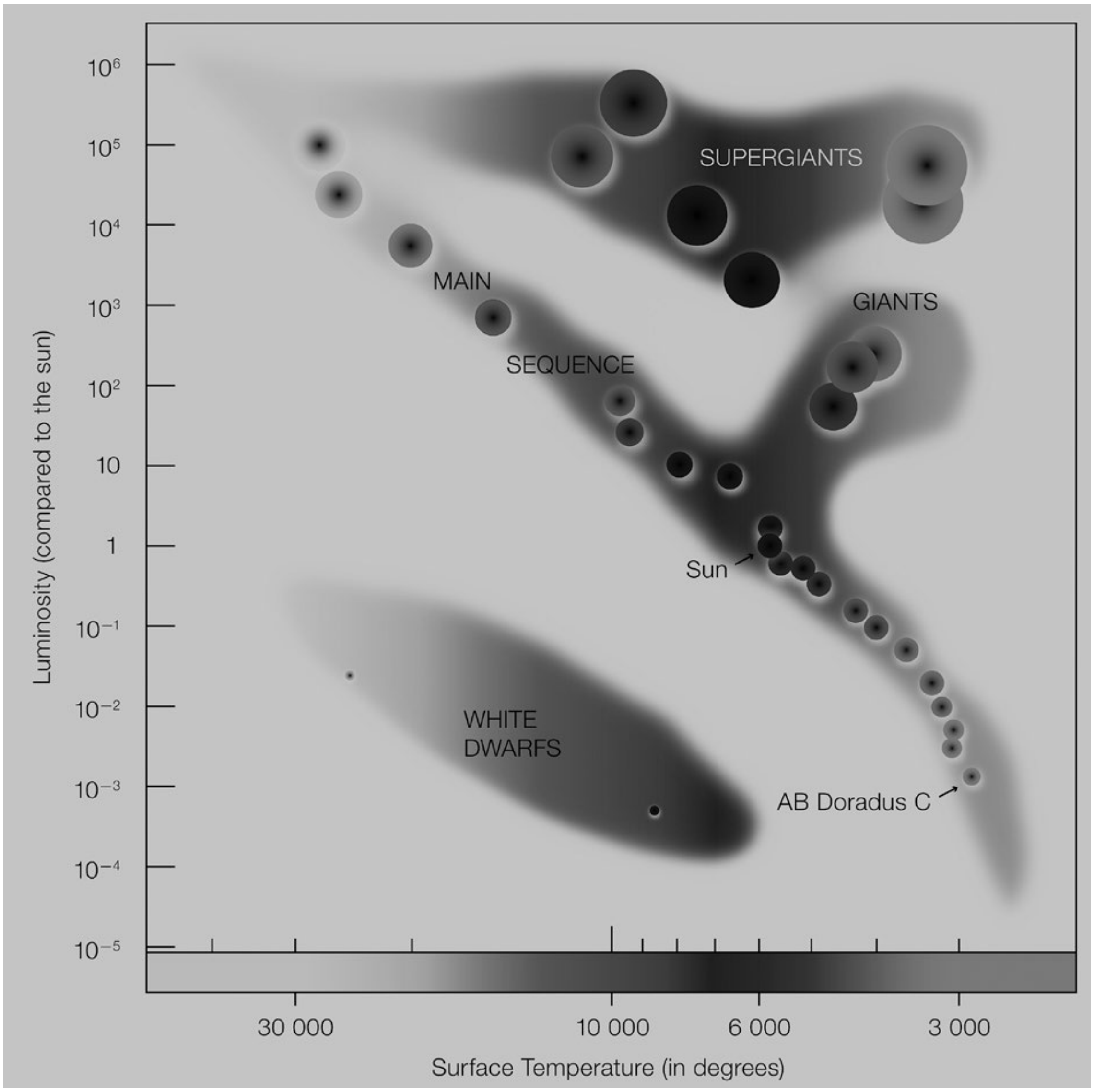

Figure 1: Hertzsprung-Russell Diagram. Credit: ESO.

Exoplanets

While scientific progress may have sewn confusion in the distinction between what stars and planets are, astronomers have continued to identify new subclasses of planets in the thriving field of exoplanetology, due to the success of exoplanet-hunting telescopes such as Kepler and CoRoT, which have identified thousands of planets orbiting other stars (NASA Exoplanet Archive, Extrasolar Planets Encyclopedia). Despite these discoveries, and perhaps wisely considering the reactions to their definition of *planet*, the IAU has not advanced the definition of *exoplanet* beyond that of the 2003 Position Statement of its Working Group on Extrasolar Planets. This statement uses the limiting mass of deuterium fusion as the boundary between planets and non-planets, while using different terms for bodies below this limit, denoting them *planets* if they orbit a star or stellar remnant, but *sub-brown dwarfs* if they do not, adding further potential for confusion (Boss *et al.* 2006: 183). Considering the lack of definitions of exoplanets and their subcategorization, we analysed a corpus of highly specialised discourse, in three leading journals in the domain of astronomy: *Monthly Notices of the Royal Astronomical Society* (*MNRAS*), *The Astrophysical Journal* (*ApJ*) and *Astronomy and Astrophysics* (*A&A*), in order to examine the definitions and criteria different authors used to divide exoplanets into different subcategories, the names of these sub-categories as well as the motivation of the terms created. NASA's Astrophysics Data System provided a single search interface for free access to full-text versions of the three journals, facilitating the identification of the earliest occurrence in each, after which the original articles were consulted, and the criteria used to establish categories of exoplanets analysed manually for the terms under analysis. The corpus analysis shows that the terms we examined were not always given the same rigid definition, but that three parameters were used in varying combinations based on available data: orbital radius, orbital period, and mass. Additional data on the specific exoplanets referenced was consulted on the *NASA Exoplanet Archive* and *The Extrasolar Planets Encyclopedia.*

The prototypical term we examined was *Hot Jupiter*. The OED's first attestation of this term is in Schilling (1996), in *Science* before appearing in the scientific journals we examined: *MNRAS* in 1999, *A&A* in 2001 and *ApJ* in 2002; this term is also the only one in the subsequently developed series that appears in the OED. Examination of the corpus shows that consensus among the scientific community has arrived at the definition of *Hot Jupiters* as having an orbital radius of less than 0.05 AU[3] and an orbital period of less than 10 days. While the use of the adjective *Hot*[4] may seem to lack the technical precision of modern astronomy, *Hot Jupiter* is nonetheless a highly efficient way to communicate large amounts of case-by-case and theoretical knowledge.

Case-by-case knowledge encompasses:

- That the mass of the planet in question is around that of Jupiter (318 Earth masses)
- The orbital period (4333 days) and radius (5.2 AU) of Jupiter.

Theoretical knowledge encompasses:

- The mass of the planet dictates its composition as being almost entirely Hydrogen
- The laws of astrophysics necessarily meaning that Hot Jupiters have orbital velocities, tidal forces and solar irradiation vastly higher than Jupiter.

The effectiveness of the term *Hot Jupiter* at communicating this information can explain the development of the additional terms *Warm Jupiter* (orbital radius approximately 0.1 AU, orbital period 10–100 days in the corpus) and the synonyms *Cool* and *Cold Jupiter*, which have orbital periods greater than 100 days and orbital radii greater than 1 AU in the corpus examined. Both *Warm* and *Cool Jupiter* were first attested in 2002 (*A&A*), while *Cold Jupiter* was first attested in 2005 in *A&A* and *ApJ*. The rivalry between *Cool* and *Cold* and the definition of the orbital period and radius remain relatively stable both over time and across journals, in spite of the fact that many Cold Jupiters are hotter than Jupiter itself. Any inconvenience in this quasi-contradiction seems outweighed by the genuine need to denote these types of planets non-ambiguously and efficiently, while also explaining the rapid adoption of the conventionalised, but arbitrary, criteria distinguishing *Hot* from *Warm* and *Cool/Cold*.

3 Astronomical Unit, the mean average distance from the Earth to the Sun, equivalent to 149,600,000 km.

4 For clarity, all terms *Adjective + Planet* are lemmatised and have initial capitals.

Following in the example of Jupiter being used as a solar system point of comparison for exoplanets, the planet Neptune subsequently emerged in a similar series of terms based on the prototype *Hot Jupiter*: Our corpus shows that *Hot/Warm Neptunes* orbit at less than 1 AU from their host star, and that *Cool/Cold Neptunes* orbit at more than 1 AU from their parent star. *Hot Neptune* is attested since 2004 in *A&A*, while *Warm Neptune* is seemingly a later creation, dating to 2011 in *A&A*. Both *Cool Neptune* and *Cold Neptune* are attested since 2006 in *ApJ*. These terms are thus inspired by, but distinct from, the series based on Jupiter, as only two sub-categories are distinguished, rather than three. Given these terms involve *Neptune* rather than *Jupiter*, the specific case-by-case information they communicate references the mass and orbital characteristics of Neptune (orbital radius of 30 AU, period of 165 years). The use of Neptune may be due Neptune being approximately 17 times Earth's mass while simultaneously being about 1/18th the mass of Jupiter, thus providing a convenient "midpoint" on the scale of masses in the solar system which also coincides with the fundamentally different compositions of Jupiter (around 90% hydrogen gas), Neptune (small rocky core, mantle of frozen water, methane and ammonia, and hydrogen atmosphere) and Earth (primarily rock and metals) (Mitton 2007: 182, 239, 347).

These distinctions have also been used to develop an additional paradigm in the corpora examined, through the combination of the prefixes *Super* and *Mini* and the planets *Jupiter, Neptune* and *Earth,* with the usage of *Super* centred on planets more than 1.5 times the mass of the reference planet, and *Mini* to denote planets ranging from 0.1 to 0.75 times the mass of the reference planet, although many exceptions do occur. The development of this paradigm thus allows for the efficient communication of both the composition and relative mass of exoplanets, harmoniously adding to the existing inventory of English structures, such as *X-size(d) planet*. These terms also allow modifications to create further subclasses through the addition of specific substances qualified by *rich* and *poor*, to create terms such as *water-rich Super Earth* or *gas-poor Super Neptune*, as well as combinations with the *Hot/Cold* paradigm, such as *Hot Super Jupiter* and *Warm Super Earth.*

The use of *dwarf* in *dwarf planet* thus seems to be of little consequence, as, even though it is not part of an entirely consistent and transparent set of terms, it is sufficient to denote a general class, with the different sub-categories of that class using entirely different terms, rather than adding additional qualifiers to the term *dwarf planet*.

Conclusion

The accepted meaning of *planet* has undergone significant change as science has progressed, with a similar problem recurring: dissimilar bodies being denoted with a single term until scientific theory advances enough for boundaries to be redrawn so that language remains both useful and efficient. The cases of Neptune and Uranus show that common usage can adapt to changes in scientific understanding, while the case of Pluto indicates not only that some ideas are more difficult to dislodge than others, but also that the use of terms can reduce their motivation for non-specialists, as seen with *dwarf,* without compromising it for specialists. The emergence of new paradigms to denote new discoveries shows that, even though some terms may not seem technical in a highly technical domain, new terms can seamlessly be coined to allow the communication of large amounts of highly specific information to the initiated, while simultaneously remaining understandable for the layperson.

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