What is A dwarf planet?

August 18 2015, by Matt Williams

n artist's concept showing the size of the best known dwarf planets compared to Earth and its moon (top). Eris is left center; Ceres is the small body to its right and Pluto and its moon Charon are at the bottom. Credit: NASA

The term dwarf planet has been tossed around a lot in recent years. As part of a three-way categorization of bodies orbiting the sun, the term was adopted in 2006 due to the discovery of objects beyond the orbit of Neptune that were comparable in size to Pluto. Since then, it has come to be used to describe many objects in our solar system, upending the old classification system that claimed there were nine planets.

The term has also led to its fair share of confusion and controversy, with many questioning its accuracy and applicability to bodies like Pluto. Nevertheless, the IAU currently recognizes five bodies within our solar system as dwarf planets, six more could be recognized in the coming years, and as many as 200 or more could exist within the expanse of the Kuiper Belt.

Definition:

According to the definition adopted by the IAU in 2006, a dwarf planet is, "a celestial body orbiting a star that is massive enough to be rounded by its own gravity but has not cleared its neighboring region of planetesimals and is not a satellite. More explicitly, it has to have sufficient mass to overcome its compressive strength and achieve hydrostatic equilibrium."

In essence, the term is meant to designate any planetary-mass object that is neither a planet nor a natural satellite that fits two basic criteria. For one, it must be in direct orbit of the sun and not be a moon around another body. Second, it must be massive enough for it to have become spherical in shape under its own gravity. And, unlike a planet, it must have not cleared the neighborhood around its orbit.

Size and Mass:

In order for a body to be become rounded, it must be sufficiently massive, to the point that its own gravity is the dominant force effecting it. Here, the internal pressure created by this mass would cause a surface to achieve plasticity, allowing high elevations to sink and hollows to fill in. This does not occur with smaller bodies that are less than a few km in diameter (such as asteroids), which are dominated forces outside of their own gravity forces and tend to maintain irregular shapes.

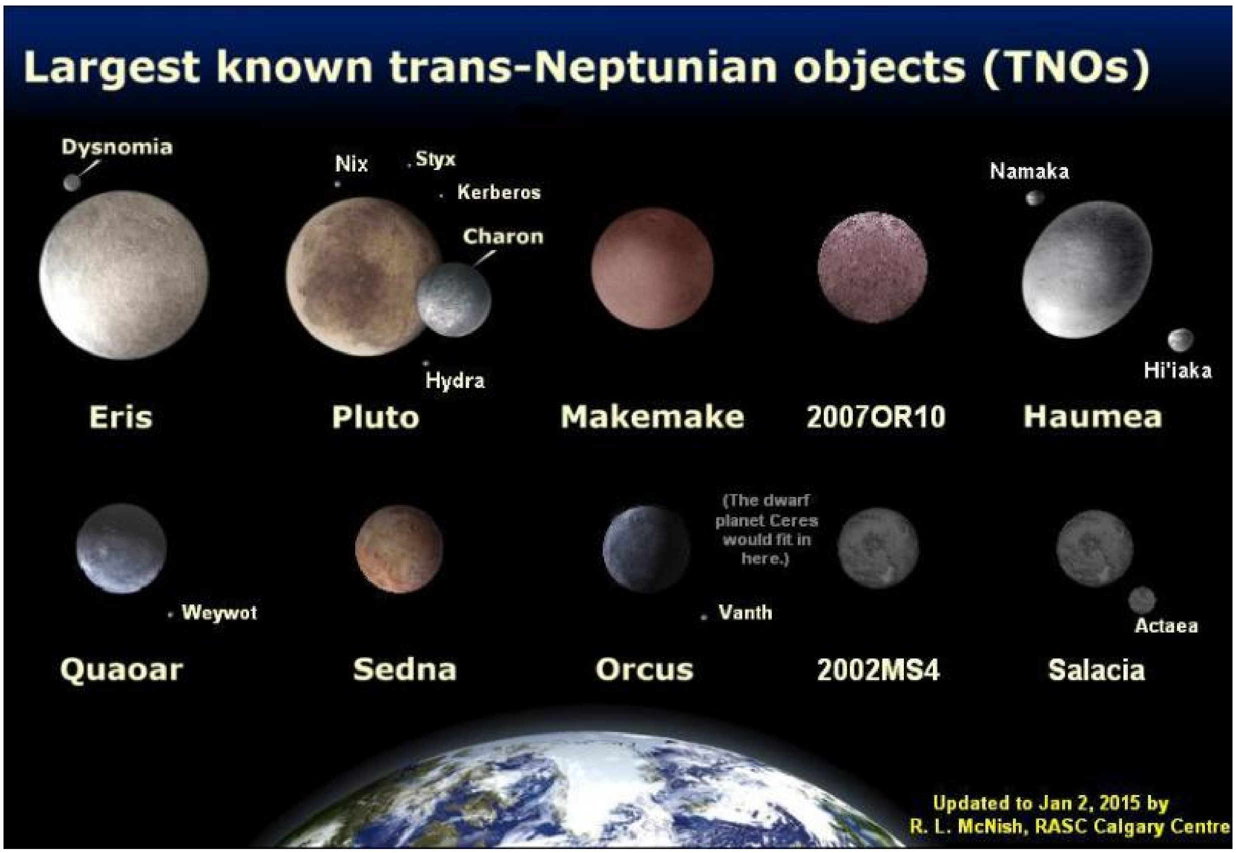
Meanwhile, bodies that measure a few kilometers across – where their gravity is more significant but not dominant – tend to be spheroid or "potato-shaped". The bigger the body is, the higher its internal pressure, until the pressure is sufficient to overcome its internal compressive strength and it achieves hydrostatic equilibrium. At this point, a body is as round as it can possibly be, given its rotation and tidal effects. This is the defining limit of a dwarf planet.

However, rotation can also affect the shape of a dwarf planet. If the body does not rotate, it will be a sphere. But the faster it does rotate, the more oblate or even scalene it becomes. The extreme example of this is Haumea, which is twice as long along its major axis as it is at the poles. Tidal forces also cause a body's rotation to gradually become tidally locked, such that it always presents the same face to its companion. An extreme example of this is the Pluto-Charon system, where both bodies are tidally locked to each other.

The upper and lower size and mass limits of dwarf planets have not been specified by the IAU. And while the lower limit is defined as the achievement of a hydrostatic equilibrium shape, the size or mass at which an object attains this shape depends on its composition and thermal history.

For example, bodies made of rigid silicates (such as rocky asteroids) should achieve hydrostatic equilibrium at a diameter of approx. 600 km and a mass of 3.4×1020 kg. For a body made of less rigid water ice, the limit would closer to 320 km and 1019 kg. As a result, no specific standard currently exists for defining a dwarf planet based on either its size or mass, but is instead more generally defined based on its shape.

Orbital Dominance:



The largest known trans-Neptunian objects (TNO), shown to scale. Credit: Larry McNish/M.Brown

In addition to hydrostatic equilibrium, many astronomers have insisted that a distinction between planets and dwarf planets be made based on the inability of the latter to "clear the neighborhood around their orbits". In short, planets are able to remove smaller bodies near their orbits by collision, capture, or gravitational disturbance (or establish orbital resonances that prevent collisions), whereas dwarf planets do not have the requisite mass to do this.

To calculate the likelihood of a planet clearing its orbit, planetary scientists Alan Stern and Harold F. Levison (the former of whom is the principal investigator of the New Horizons mission to Pluto and the Chief Scientist at Moon Express) introduced a parameter they designated as ? (lambda).

This parameter expresses the likelihood of an encounter resulting in a given deflection of an object's orbit. The value of this parameter in Stern's model is proportional to the square of the mass and inversely proportional to the period, and can be used to estimate the capacity of a body to clear the neighborhood of its orbit.

Astronomers like Steven Soter, the scientist-in-residence for NYU and a Research Associate at the American Museum of Natural History, have advocated using this parameter to differentiate between planets and dwarf planets. Soter has also proposed a parameter he refers to as the planetary discriminant – designated as μ (mu) – which is calculated by dividing the mass of the body by the total mass of the other objects that share its orbit.

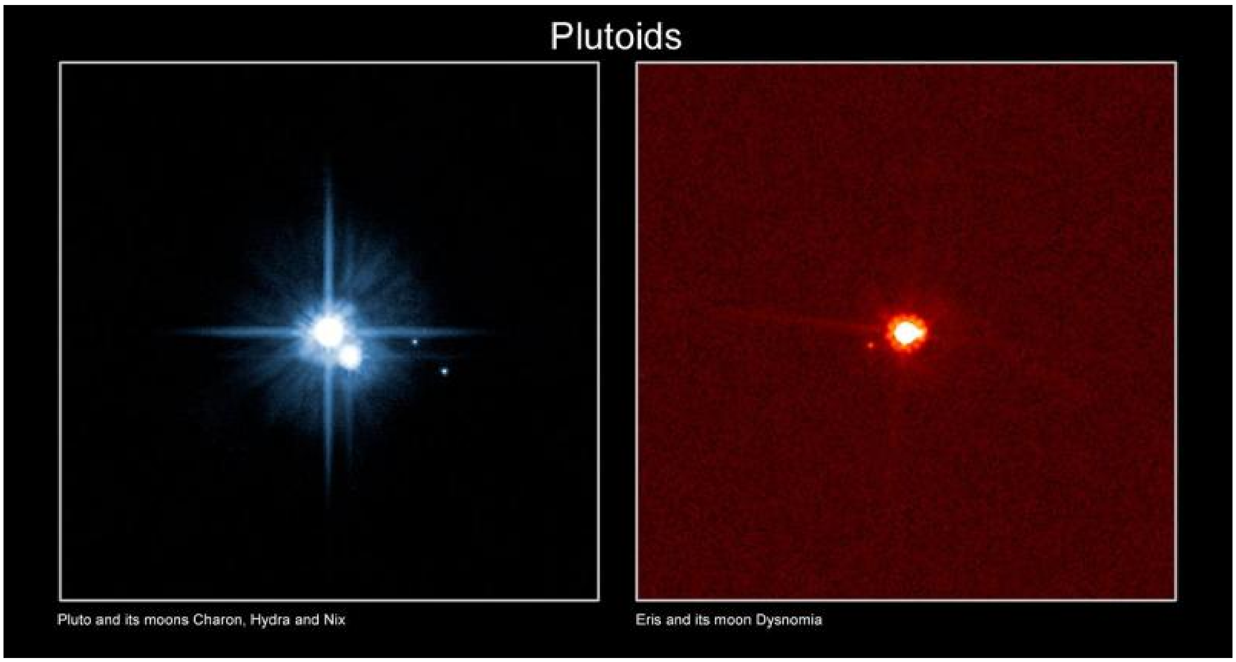
Recognized and Possible Dwarf Planets:

There are currently five dwarf planets: Pluto, Eris, Makemake, Haumea, and Ceres. Only Ceres and Pluto have been observed enough to indisputably fit into the category. The IAU decided that unnamed Trans-Neptunian Objects (TNOs) with an absolute magnitude brighter than +1 (and a mathematically delimited minimum diameter of 838 km) are to be named as dwarf planets.

Possible candidates that are currently under consideration include Orcus, 2002 MS4, Salacia, Quaoar, 2007 OR10, and Sedna. All of these objects are located in the Kuiper Belt or the Scattered Disc; with the exception of Sedna, which is a detached object – a special class that applies to dynamic TNOs in the outer solar system.

It is possible that there are another 40 known objects in the solar system that could be rightly classified as dwarf planets. Estimates are that up to 200 dwarf planets may be found when the entire region known as the Kuiper belt is explored, and that the number may exceed 10,000 when objects scattered outside the Kuiper belt are considered.

Contention:



Pluto and moons Charon, Hydra and Nix (left) compared to the dwarf planet Eris and its moon Dysmonia (right). Credit: International Astronomical Union

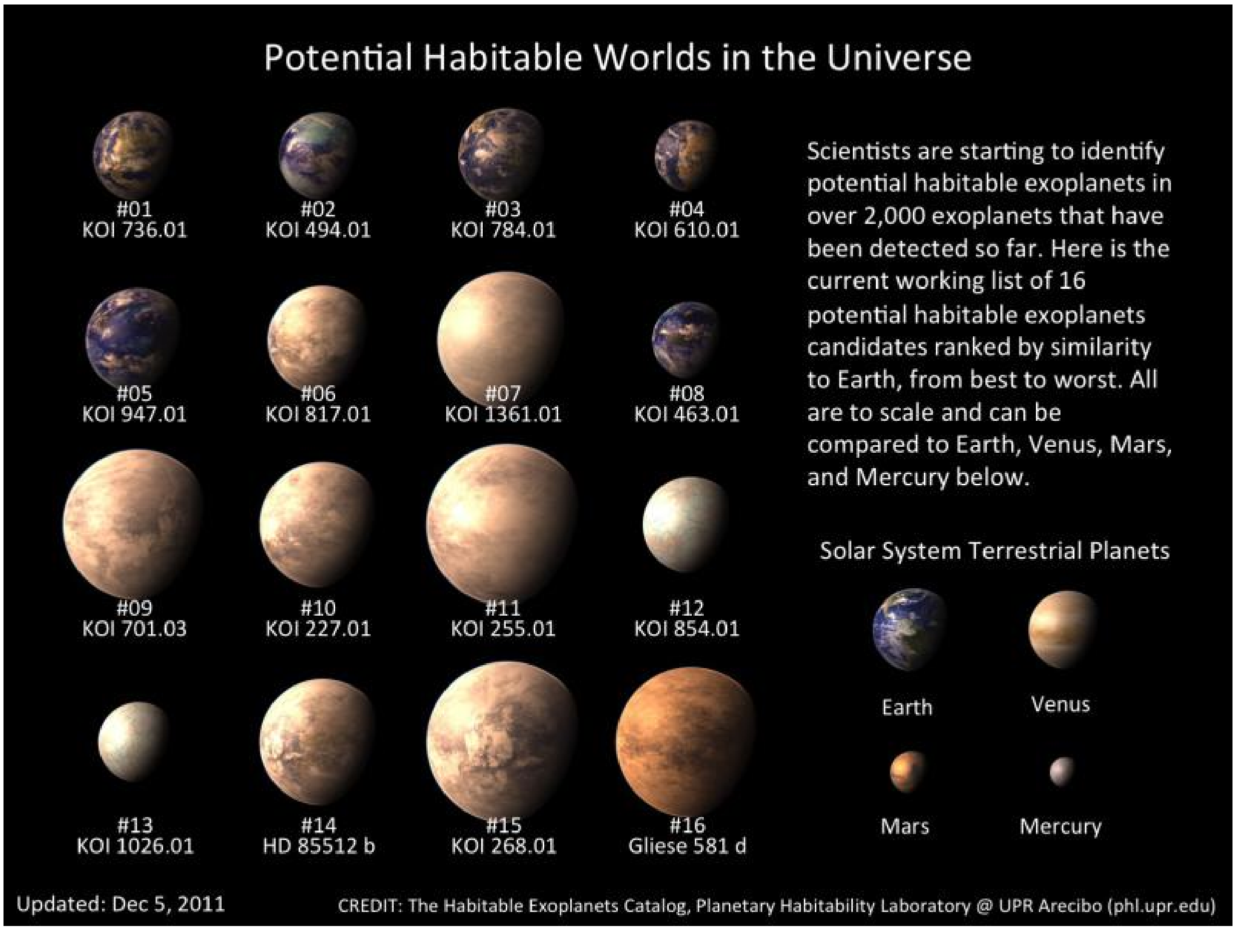
In the immediate aftermath of the IAU decision regarding the definition of a planet, a number of scientists expressed their disagreement with the IAU resolution. Mike Brown (the leader of the Caltech team that discovered Eris) agrees with the reduction of the number of planets to eight. However, astronomers like Alan Stern have voiced criticism over the IAUs definition.

Stern has contended that much like Pluto, Earth, Mars, Jupiter, and Neptune have not fully cleared their orbital zones. Earth orbits the sun with 10,000 near-Earth asteroids, which in Stern's estimation contradicts the notion that it has cleared its orbit. Jupiter, meanwhile, is accompanied by a whopping 100,000 Trojan asteroids on its orbital path.

Thus, in 2011, Stern still referred to Pluto as a planet and accepted other dwarf planets such as Ceres and Eris, as well as the larger moons, as additional planets. However, other astronomers have countered this opinion by saying that, far from not having cleared their orbits, the major planets completely control the orbits of the other bodies within their orbital zone.

Another point of contention is the application of this new definition to planets outside of the solar system. Techniques for identifying extrasolar objects generally cannot determine whether an object has "cleared its orbit", except indirectly. As a result, a separate "working" definition for extrasolar planets was established by the IAU in 2001 and includes the criterion that, "The minimum mass/size required for an extrasolar object to be considered a planet should be the same as that used in the solar system."

Beyond the content of the IAU's decision, there is also the controversy surrounding the decision process itself. Essentially, the final vote involved a relatively small percentage of the IAU General Assembly – 425 out of 9000, or less than 5%. This was due in part to the timing of the vote, which happened on the final day of the ten-day event when many members had already left.



How the current IAU definition applies to exoplanets is a source of controversy for many astronomers. Credit: phl.upl.edu

However, supporters of the decision emphasize that a sampling of 400 representative out of a population of 9,000 statistically yields a result with good accuracy. Ergo, even if only 4-5% of the members voted in favor of reclassifying Pluto, the fact that the majority of said members agreed could be taken as a sampling of IAU opinion as a whole.

There is also the issue of the many astronomers who were unable to attend to the conference or who chose not to make the trip to Prague. Astronomer Marla Geha has also clarified that not all members of the Union were needed to vote on the classification issue, and that only those whose work is directly related to planetary studies needed to be involved.

Lastly, NASA has announced that it will use the new guidelines established by the IAU, which constitutes an endorsement or at least acceptance of the IAUs position. Nevertheless, the controversy surrounding the 2006 decision is by no means over, and we can expect further developments on this front as more "dwarf planets" are found and designated.

Understanding what is a dwarf planet according to the IAU is easy enough, but making the solar system fit into a three tiered classification system will prove increasingly difficult as our understanding of the universe increases and we are able to see farther and farther into space.

Source: Universe Today

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