= Dwarf planet =

A dwarf planet is a planetary @-@ mass object that is neither a planet nor a natural satellite . That is , it is in direct orbit of the Sun , and is massive enough for its gravity to crush itself into a hydrostatic equilibrium shape (usually a spheroid) , but has not cleared the neighborhood of other material around its orbit .

The term dwarf planet was adopted in 2006 as part of a three @-@ way categorization of bodies orbiting the Sun , brought about by an increase in discoveries of objects farther away from the Sun than Neptune that rivaled Pluto in size , and finally precipitated by the discovery of an even more massive object , Eris . The exclusion of dwarf planets from the roster of planets by the IAU has been both praised and criticized ; it was said to be the " right decision " by astronomer Mike Brown , who discovered Eris and other new dwarf planets , but has been rejected by Alan Stern , who had coined the term dwarf planet in April 1991 .

The International Astronomical Union (IAU) currently recognizes five dwarf planets : Ceres , Pluto , Haumea , Makemake , and Eris . Brown criticizes this official recognition : " A reasonable person might think that this means that there are five known objects in the solar system which fit the IAU definition of dwarf planet , but this reasonable person would be nowhere close to correct . "

It is suspected that another hundred or so known objects in the Solar System are 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 . Individual astronomers recognize several of these , and in August 2011 Mike Brown published a list of 390 candidate objects , ranging from " nearly certain " to " possible " dwarf planets . Brown currently identifies eleven known objects ? the five accepted by the IAU plus 2007 OR10 , Quaoar , Sedna , Orcus , (307261) 2002 MS4 and Salacia ? as " virtually certain " , with another dozen highly likely . Stern states that there are more than a dozen known dwarf planets .

However , only two of these bodies , Ceres and Pluto , have been observed in enough detail to demonstrate that they actually fit the IAU 's definition . The IAU accepted Eris as a dwarf planet because it is more massive than Pluto . They subsequently decided that unnamed trans @-@ Neptunian objects with an absolute magnitude brighter than + 1 (and hence a diameter of ? 838 km assuming a geometric albedo of ? 1) are to be named under the assumption that they are dwarf planets . The only two such objects known at the time , Makemake and Haumea , went through this naming procedure and were declared to be dwarf planets . The question of whether other likely objects are dwarf planets has never been addressed by the IAU .

The classification of bodies in other planetary systems with the characteristics of dwarf planets has not been addressed .

= = History of the concept = =

Starting in 1801 , astronomers discovered Ceres and other bodies between Mars and Jupiter which were for some decades considered to be planets . Between then and around 1851 , when the number of planets had reached 23 , astronomers started using the word asteroid for the smaller bodies and then stopped naming or classifying them as planets .

With the discovery of Pluto in 1930 , most astronomers considered the Solar System to have nine planets , along with thousands of significantly smaller bodies (asteroids and comets) . For almost 50 years Pluto was thought to be larger than Mercury , but with the discovery in 1978 of Pluto 's moon Charon , it became possible to measure Pluto 's mass accurately and to determine that it was much smaller than in initial estimates . It was roughly one @-@ twentieth the mass of Mercury , which made Pluto by far the smallest planet . Although it was still more than ten times as massive as the largest object in the asteroid belt , Ceres , it was one @-@ fifth that of Earth 's Moon . Furthermore , having some unusual characteristics , such as large orbital eccentricity and a high orbital inclination , it became evident it was a completely different kind of body from any of the other planets .

In the 1990s , astronomers began to find objects in the same region of space as Pluto (now known as the Kuiper belt) , and some even farther away . Many of these shared several of Pluto 's key orbital characteristics , and Pluto started being seen as the largest member of a new class of objects , plutinos . This led some astronomers to stop referring to Pluto as a planet . Several terms , including subplanet and planetoid , started to be used for the bodies now known as dwarf planets . By 2005 , three trans @-@ Neptunian objects comparable in size to Pluto (Quaoar , Sedna , and Eris) had been reported . It became clear that either they would also have to be classified as planets , or Pluto would have to be reclassified . Astronomers were also confident that more objects as large as Pluto would be discovered , and the number of planets would start growing quickly if Pluto were to remain a planet .

Eris (then known as 2003 UB313) was discovered in January 2005 , which was thought to be slightly larger than Pluto , and some reports informally referred to it as the tenth planet . As a consequence , the issue became a matter of intense debate during the IAU General Assembly in August 2006 . The IAU 's initial draft proposal included Charon , Eris , and Ceres in the list of planets . After many astronomers objected to this proposal , an alternative was drawn up by Uruguayan astronomer Julio Ángel Fernández , in which he created a median classification for objects large enough to be round but that had not cleared their orbits of planetesimals . Dropping Charon from the list , the new proposal also removed Pluto , Ceres , and Eris , because they have not cleared their orbits .

The IAU 's final Resolution 5A preserved this three @-@ category system for the celestial bodies orbiting the Sun . It reads :

The IAU ... resolves that planets and other bodies , except satellites , in our Solar System be defined into three distinct categories in the following way :

(1) A planet1 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 .

(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 neighbourhood 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 either dwarf planet or other status .

3 These currently include most of the Solar System asteroids , most Trans @-@ Neptunian Objects (TNOs) , comets , and other small bodies .

Although concerns were raised about the classification of planets orbiting other stars , the issue was not resolved ; it was proposed instead to decide this only when such objects start being observed .

= = Name = =

The term dwarf planet has itself been somewhat controversial , as it implies that these bodies are planets , much as dwarf stars are stars . This is the conception of the Solar System that Stern promoted when he coined the phrase . The older word planetoid (" having the form of a planet ") has no such connotation , and is also used by astronomers for bodies that fit the IAU definition . Brown states that planetoid is " a perfectly good word " that has been used for these bodies for years , and that the use of the term dwarf planet for a non @-@ planet is " dumb " , but that it was motivated by an attempt by the IAU division III plenary session to reinstate Pluto as a planet in a second resolution . Indeed , the draft of Resolution 5A had called these median bodies planetoids , but the plenary session voted unanimously to change the name to dwarf planet . The second

resolution , 5B , defined dwarf planets as a subtype of planet , as Stern had originally intended , distinguished from the other eight that were to be called " classical planets " . Under this arrangement , the twelve planets of the rejected proposal were to be preserved in a distinction between eight classical planets and four dwarf planets . However , Resolution 5B was defeated in the same session that 5A was passed . Because of the semantic inconsistency of a dwarf planet not being a planet due to the failure of Resolution 5B , alternative terms such as nanoplanet and subplanet were discussed , but there was no consensus among the CSBN to change it .

In most languages equivalent terms have been created by translating dwarf planet more @-@ or @-@ less literally : French planète naine , Spanish planeta enano , German Zwergplanet , Russian karlikovaya planeta (?????????? ???????) , Arabic kaukab qazm (???? ???) , Chinese ?ixíngx?ng (???) , Korean waesohangseong (???? ; ????) , but Japanese and Latin are exceptions : In Japanese they are called junwakusei (???) meaning " subplanets " or " almost @-@ planets " , and the modern Latin name , planetula (or planetion following the Greek) , is a diminutive derivation of planeta , hence also meaning something less than a planet .

IAU Resolution 6a of 2006 recognizes Pluto as " the prototype of a new category of trans @-@ Neptunian objects " . The name and precise nature of this category were not specified but left for the IAU to establish at a later date ; in the debate leading up to the resolution , the members of the category were variously referred to as plutons and plutonian objects but neither name was carried forward , perhaps due to objections from geologists that this would create confusion with their pluton . On June 11 , 2008 , the IAU Executive Committee announced a name , plutoid , and a definition : all trans @-@ Neptunian dwarf planets are plutoids , though " in part because of an email miscommunication , the WG @-@ PSN [Working Group for Planetary System Nomenclature] was not involved in choosing the word plutoid . ... In fact , a vote taken by the WG @-@ PSN subsequent to the Executive Committee meeting has rejected the use of that speci?c term " , and it has not come into common use among astronomers .

= = Characteristics = =

= = = Orbital dominance = = =

Alan Stern and Harold F. Levison introduced a parameter ? (lambda) , expressing the likelihood of an encounter resulting in a given deflection of orbit . The value of this parameter in Stern 's model is proportional to the square of the mass and inversely proportional to the period . This value can be used to estimate the capacity of a body to clear the neighbourhood of its orbit , where ? > 1 will eventually clear it . A gap of five orders of magnitude in ? was found between the smallest terrestrial planets and the largest asteroids and Kuiper belt objects .

Using this parameter , Steven Soter and other astronomers argued for a distinction between planets and dwarf planets based on the inability of the latter to " clear the neighbourhood around their orbits " : 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 lack the mass to do so . Soter went on to propose a parameter he called the planetary discriminant , designated with the symbol µ (mu) , that represents an experimental measure of the actual degree of cleanliness of the orbital zone (where µ is calculated by dividing the mass of the candidate body by the total mass of the other objects that share its orbital zone) , where µ > 100 is deemed to be cleared . There are several other schemes that try to differentiate between planets and dwarf planets , but the 2006 definition uses this concept .

= = = Hydrostatic equilibrium = = =

Sufficient internal pressure , caused by the body 's gravitation , will turn a body plastic , and sufficient plasticity will allow high elevations to sink and hollows to fill in , a process known as gravitational relaxation . Bodies smaller than a few kilometers are dominated by non @-@

gravitational forces and tend to have an irregular shape . Larger objects , where gravitation is significant but not dominant , are " potato " shaped ; the more massive the body is , the higher its internal pressure and the more rounded its shape , 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 is possible to be , given its rotation and tidal effects , and is an ellipsoid in shape . This is the defining limit of a dwarf planet .

When an object is in hydrostatic equilibrium , a global layer of liquid covering its surface would form a liquid surface of the same shape as the body , apart from small @-@ scale surface features such as craters and fissures . 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 . However , if such a rotating body were to be heated until it melted , its overall shape would not change when liquid . The extreme example of a non @-@ spherical body in hydrostatic equilibrium is Haumea , which is twice as long along its major axis as it is at the poles . If the body has a massive nearby companion , then tidal forces come into effect as well , distorting it into a prolate spheroid . An example of this is Jupiter 's moon Io , which is the most volcanically active body in the Solar System due to effects of tidal heating . 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 . Earth 's Moon is also tidally locked , as are many satellites of the gas giants .

The upper and lower size and mass limits of dwarf planets have not been specified by the IAU . There is no defined upper limit , and an object larger or more massive than Mercury that has not " cleared the neighbourhood around its orbit " would be classified as a dwarf planet . The lower limit is determined by the requirements of achieving a hydrostatic equilibrium shape , but the size or mass at which an object attains this shape depends on its composition and thermal history . The original draft of the 2006 IAU resolution redefined hydrostatic equilibrium shape as applying " to objects with mass above 5 × 1020 kg and diameter greater than 800 km " , but this was not retained in the final draft .

Empirical observations suggest that the lower limit will vary according to the composition and thermal history of the object . For a body made of rigid silicates , such as the stony asteroids , the transition to hydrostatic equilibrium should occur at a diameter of approximately 600 km and a mass of some 3 @.@ 4 × 1020 kg . For a body made of less rigid water ice , the limit should be about 320 km and 1019 kg . In the asteroid belt , Ceres is the only body that clearly surpasses the silicaceous limit (though it is actually a rocky ? icy body) , and its shape is an equilibrium spheroid . 2 Pallas and 4 Vesta , however , are rocky and are just below the limit . Pallas , at 525 ? 560 km and 1 @.@ 85 ? 2 @.@ 4 × 1020 kg , is " nearly round " but still somewhat irregular . Vesta , at 530 km and 2 @.@ 6 × 1020 kg , deviates from an ellipsoid shape primarily due to a large impact basin at its pole .

= = Dwarf planets and possible dwarf planets = =

Many trans @-@ Neptunian objects (TNOs) are thought to have icy cores and therefore would require a diameter of perhaps 400 km (250 mi) ? only about 3 % of that of Earth ? to relax into gravitational equilibrium . As of January 2015 , about 150 known TNOs are thought to be probably dwarf planets , although only rough estimates of the diameters of most of these objects are available . A team is investigating thirty of these , and think that the number will eventually prove to be around 200 in the Kuiper belt , with thousands more beyond .

The IAU has recognized five bodies as dwarf planets since 2008 : Ceres , Pluto , Eris , Haumea , and Makemake . Ceres and Pluto are known to be dwarf planets through direct observation . Eris is recognized as a dwarf planet because it is more massive than Pluto (measurements by New Horizons indicate that Pluto 's diameter is larger than that of Eris) , whereas Haumea and Makemake qualify based on their absolute magnitudes . In relative distance from the Sun , the five are :

Ceres ? ? discovered on January 1 , 1801 , 45 years before Neptune . Considered a planet for half

a century before reclassification as an asteroid . Accepted as a dwarf planet by the IAU on September 13 , 2006 .

Pluto ? ? discovered on February 18 , 1930 . Classified as a planet for 76 years . Reclassified as a dwarf planet by the IAU on August 24 , 2006 .

Haumea ? discovered on December 28 , 2004 . Accepted by the IAU as a dwarf planet on September 17 , 2008 .

Makemake ? discovered on March 31 , 2005 . Accepted by the IAU as a dwarf planet on July 11 , 2008 .

Eris ? discovered on January 5 , 2005 . Called the " tenth planet " in media reports . Accepted by the IAU as a dwarf planet on September 13 , 2006 .

Mike Brown considers an additional six trans @-@ Neptunian objects to be " nearly certainly " dwarf planets with diameters at or above 900 kilometers . These objects are :

Orcus ? discovered on February 17 , 2004

2002 MS4 ? discovered on 18 June 2002

Salacia ? discovered on September 22 , 2004

Quaoar ? discovered on June 5 , 2002

2007 OR10 ? discovered on July 17 , 2007

Sedna ? discovered on November 14 , 2003

Tancredi et al. advised the IAU to officially accept Orcus , Sedna and Quaoar . In addition , Gonzalo Tancredi considers the five TNOs Varuna , Ixion , 2003 AZ84 , 2004 GV9 , and 2002 AW197 to be dwarf planets as well . These objects are also recognized by Mike Brown and classified as " highly likely " . An extensive table compares the dwarf planet candidates of the two planetary astronomers in detail .

Vesta , the next @-@ most @-@ massive body in the asteroid belt after Ceres , is roughly spherical , deviating mainly because of massive impacts that formed Rheasilvia and Veneneia crater after it solidified . Furthermore , its triaxial dimensions are not consistent with hydrostatic equilibrium . Triton is thought to be a captured dwarf planet . Phoebe is a captured body that , like Vesta , is no longer in hydrostatic equilibrium , but is thought to have been so early in its history .

= = Exploration = =

On March 6 , 2015 , the Dawn spacecraft began to orbit Ceres , becoming the first spacecraft to orbit a dwarf planet . On 14 July 2015 , the New Horizons space probe flew by Pluto and its five moons . Dawn has also explored the former dwarf planet , Vesta . Phoebe has been explored by Cassini (most recently) and Voyager 2 , which also explored Triton . These three are thought to be former dwarf planets and therefore their exploration helps in the study of the evolution of dwarf planets .

= = Contention = =

In the immediate aftermath of the IAU definition of dwarf planet , a number of scientists expressed their disagreement with the IAU resolution . Campaigns included car bumper stickers and T @-@ shirts . Mike Brown (the discoverer of Eris) agrees with the reduction of the number of planets to eight .

NASA has announced that it will use the new guidelines established by the IAU . However , Alan Stern , the director of NASA 's mission to Pluto , rejects the current IAU definition of planet , both in terms of defining dwarf planets as something other than a type of planet , and in using orbital characteristics (rather than intrinsic characteristics) of objects to define them as dwarf planets . Thus , in 2011 , he 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 . Several years before the IAU definition , he used orbital characteristics to separate " überplanets " (the dominant eight) from " unterplanets " (the dwarf planets) , considering both types " planets " .

= = Planetary @-@ mass moons = =

Nineteen moons are known to be massive enough to have relaxed into a rounded shape under their own gravity , and seven of them are more massive than either Eris or Pluto . They are not physically distinct from the dwarf planets , but are not dwarf planets because they do not directly orbit the Sun . The seven that are more massive than Eris are the Moon , the four Galilean moons of Jupiter (Io , Europa , Ganymede , and Callisto) , one moon of Saturn (Titan) , and one moon of Neptune (Triton) . The others are six moons of Saturn (Mimas , Enceladus , Tethys , Dione , Rhea , and Iapetus) , five moons of Uranus (Miranda , Ariel , Umbriel , Titania , and Oberon) , and one moon of Pluto (Charon) . There are additional possibilities among TNOs , including Dysnomia orbiting Eris . Alan Stern calls these moons " satellite planets " , one of three categories of planet together with dwarf planets and classical planets . The term planemo (" planetary @-@ mass object ") covers all three .

In a draft resolution for the IAU definition of planet , both Pluto and Charon would have been considered dwarf planets in a binary system , given that they both satisfied the mass and shape requirements for dwarf planets and revolved around a common center of mass located between the two bodies (rather than within one of the bodies) . The IAU currently states that Charon is not considered to be a dwarf planet and is just a satellite of Pluto , although the idea that Charon might qualify to be a dwarf planet in its own right may be considered at a later date . The location of the barycenter depends not only on the relative masses of the bodies , but also on the distance between them ; the barycenter of the Sun ? Jupiter orbit , for example , lies outside the Sun .