= Haumea =

Haumea , minor @-@ planet designation 136108 Haumea , is a dwarf planet located beyond Neptune 's orbit . It was discovered in 2004 by a team headed by Mike Brown of Caltech at the Palomar Observatory in the United States and independently in 2005 , by a team headed by José Luis Ortiz Moreno at the Sierra Nevada Observatory in Spain , though the latter claim has been contested . On September 17 , 2008 , it was recognized as a dwarf planet by the International Astronomical Union (IAU) and named after Haumea , the Hawaiian goddess of childbirth .

Haumea 's mass is about one @-@ third that of Pluto , and 1 / 1400 that of Earth . Although its shape has not been directly observed , calculations from its light curve indicate that it is a triaxial ellipsoid , with its major axis twice as long as its minor . Its gravity is thought to be sufficient for it to have relaxed into hydrostatic equilibrium , making it a dwarf planet . Haumea 's elongated shape together with its rapid rotation , high density , and high albedo (from a surface of crystalline water ice) , are thought to be the consequences of a giant collision , which left Haumea the largest member of a collisional family that includes several large trans @-@ Neptunian objects (TNOs) and Haumea 's two known moons , Hi?iaka and Namaka .

= = History = =

= = = Discovery = = =

Two teams claim credit for the discovery of Haumea . Mike Brown and his team at Caltech discovered Haumea in December 2004 on images they had taken on May 6 , 2004 . On July 20 , 2005 , they published an online abstract of a report intended to announce the discovery at a conference in September 2005 . At around this time , José Luis Ortiz Moreno and his team at the Instituto de Astrofísica de Andalucía at Sierra Nevada Observatory in Spain found Haumea on images taken on March 7 ? 10 , 2003 . Ortiz emailed the Minor Planet Center with their discovery on the night of July 27 , 2005 .

Brown initially conceded discovery credit to Ortiz , but came to suspect the Spanish team of fraud upon learning that his observation logs were accessed from the Spanish observatory the day before the discovery announcement . These logs included enough information to allow the Ortiz team to precover Haumea in their 2003 images , and they were accessed again just before Ortiz scheduled telescope time to obtain confirmation images for a second announcement to the MPC on July 29 . Ortiz later admitted he had accessed the Caltech observation logs but denied any wrongdoing , stating he was merely verifying whether they had discovered a new object .

IAU protocol is that discovery credit for a minor planet goes to whoever first submits a report to the MPC (Minor Planet Center) with enough positional data for a decent determination of its orbit , and that the credited discoverer has priority in choosing a name . However , the IAU announcement on September 17 , 2008 , that Haumea had been accepted as a dwarf planet , did not mention a discoverer . The location of discovery was listed as the Sierra Nevada Observatory of the Spanish team , but the chosen name , Haumea , was the Caltech proposal ; Ortiz 's team had proposed " Ataecina " , named for the ancient Iberian goddess of Spring .

= = = Name = = =

Until it was given a permanent name , the Caltech discovery team used the nickname " Santa " among themselves , because they had discovered Haumea on December 28 , 2004 , just after Christmas . The Spanish team were the first to file a claim for discovery to the Minor Planet Center , in July 2005 . On July 29 , 2005 , Haumea was given the provisional designation 2003 EL61 , based on the date of the Spanish discovery image . On September 7 , 2006 , it was numbered and admitted into the official minor planet catalogue as (136108) 2003 EL61 .

Following guidelines established by the IAU that classical Kuiper belt objects be given names of

mythological beings associated with creation , in September 2006 the Caltech team submitted formal names from Hawaiian mythology to the IAU for both (136108) 2003 EL61 and its moons , in order " to pay homage to the place where the satellites were discovered " . The names were proposed by David Rabinowitz of the Caltech team . Haumea is the matron goddess of the island of Hawai?i , where the Mauna Kea Observatory is located . In addition , she is identified with Papa , the goddess of the earth and wife of W?kea (space) , which is appropriate because Haumea is thought to be composed almost entirely of solid rock , without the thick ice mantle over a small rocky core typical of other known Kuiper belt objects . Lastly , Haumea is the goddess of fertility and childbirth , with many children who sprang from different parts of her body ; this corresponds to the swarm of icy bodies thought to have broken off the dwarf planet during an ancient collision . The two known moons , also believed to have formed in this manner , are thus named after two of Haumea 's daughters , Hi?iaka and N?maka .

The proposal by the Ortiz team , Ataecina , did not meet IAU naming requirements , because Ataecina is not a creation deity . (See Ataecina § Dwarf planet .)

= = Classification = =

Haumea is a plutoid , a dwarf planet beyond Neptune 's orbit . Its classification as a dwarf planet means it is presumed to be massive enough to have been rounded by its own gravity into a shape in hydrostatic equilibrium , but not massive enough to have cleared its neighbourhood of similar objects . Haumea appears to have a triaxial ellipsoid shape resulting its rapid rotation complicated by tidal interactions with its moons . This contrasts with the simpler oblate shape typically assumed by less rapidly rotating astronomical bodies such as the Earth , Jupiter (or a water balloon tossed with moderate spin) . Like the earth , Haumea is flattened at the poles (indeed much more so) , but its equator , instead of being round like the Earth 's , is elliptical , with two big bulges 180 degrees apart in longitude , buoyed up , as it were , by the greater centrifugal force they experience by virtue of being farther from the axis of rotation . In other words , Haumea is spinning so fast that if it spun much faster these bulges would distort into a dumbbell shape and split the planet in two . Haumea was initially listed as a classical Kuiper belt object in 2006 by the Minor Planet Center , but no longer . The nominal trajectory suggests that it is in the weak 7 : 12 resonance with Neptune (orbiting the Sun 7 times for every 12 orbits of Neptune) , because its perihelion distance of 35 AU is near the limit of stability with Neptune . There are precovery images of Haumea dating back to March 22 , 1955 from the Palomar Mountain Digitized Sky Survey . Further observations of the orbit will be required to verify its dynamic status .

= = Orbit and rotation = =

Haumea has an orbital period of 284 Earth years , a perihelion of 35 AU , and an orbital inclination of 28 ° . It passed aphelion in early 1992 , and is currently more than 50 AU from the Sun . Haumea 's orbit has a slightly greater eccentricity than that of the other members of its collisional family . This is thought to be due to Haumea 's weak 7 : 12 orbital resonance with Neptune gradually modifying its initial orbit over the course of a billion years , through the Kozai effect , which allows the exchange of an orbit 's inclination for increased eccentricity .

With a visual magnitude of 17 @.@ 3 , Haumea is the third @-@ brightest object in the Kuiper belt after Pluto and Makemake , and easily observable with a large amateur telescope . However , because the planets and most small Solar System bodies share a common orbital alignment from their formation in the primordial disk of the Solar System , most early surveys for distant objects focused on the projection on the sky of this common plane , called the ecliptic . As the region of sky close to the ecliptic became well explored , later sky surveys began looking for objects that had been dynamically excited into orbits with higher inclinations , as well as more distant objects , with slower mean motions across the sky . These surveys eventually covered the location of Haumea , with its high orbital inclination and current position far from the ecliptic .

Haumea displays large fluctuations in brightness over a period of 3 @.@ 9 hours , which can only

be explained by a rotational period of this length . This is faster than any other known equilibrium body in the Solar System , and indeed faster than any other known body larger than 100 km in diameter . This rapid rotation is thought to have been caused by the impact that created its satellites and collisional family .

= = Physical characteristics = =

Because Haumea has moons , the mass of the system can be calculated from their orbits using Kepler 's third law . The result is 4 @.@ 2 × 1021 kg , 28 % the mass of the Plutonian system and 6 % that of the Moon . Nearly all of this mass is in Haumea .

= = = Size , shape , and composition = = =

The size of a Solar System object can be deduced from its optical magnitude , its distance , and its albedo . Objects appear bright to Earth observers either because they are large or because they are highly reflective . If their reflectivity (albedo) can be ascertained , then a rough estimate can be made of their size . For most distant objects , the albedo is unknown , but Haumea is large and bright enough for its thermal emission to be measured , which has given an approximate value for its albedo and thus its size . However , the calculation of its dimensions is complicated by its rapid rotation . The rotational physics of deformable bodies predicts that over as little as a hundred days , a body rotating as rapidly as Haumea will have been distorted into the equilibrium form of a triaxial ellipsoid . It is thought that most of the fluctuation in Haumea 's brightness is caused not by local differences in albedo but by the alternation of the side view and end view as seen from Earth .

The rotation and amplitude of Haumea 's light curve place strong constraints on its composition . If Haumea had a low density like Pluto , with a thick mantle of ice over a small rocky core , its rapid rotation would have elongated it to a greater extent than the fluctuations in its brightness allow . Such considerations constrain its density to a range of 2 @.@ 6 ? 3 @.@ 3 g / cm3 . By comparison , the Moon , which is rocky , has a density of 3 @.@ 3 g / cm3 , whereas Pluto , which is typical of icy objects in the Kuiper belt , has a density of 1 @.@ 86 g / cm3 . Haumea 's possible density covers the values for silicate minerals such as olivine and pyroxene , which make up many of the rocky objects in the Solar System . This suggests that the bulk of Haumea is rock covered with a relatively thin layer of ice . A thick ice mantle more typical of Kuiper belt objects may have been blasted off during the impact that formed the Haumean collisional family .

The denser the object in hydrostatic equilibrium , the more spherical it must be for a given rotational period , placing constraints on Haumea 's possible dimensions . Fitting its accurately known mass , its rotation , and its inferred density to an equilibrium ellipsoid predicts that Haumea is approximately the diameter of Pluto along its longest axis and about half that at its poles . Because no observations of occultations of stars by Haumea or occultations of the dwarf planet with its moons have yet been made , direct , precise measurements of its dimensions , like those that were made for Pluto , do not yet exist .

Several ellipsoid @-@ model calculations of Haumea 's dimensions have been made . The first model produced after Haumea 's discovery was calculated from ground @-@ based observations of Haumea 's light curve at optical wavelengths : it provided a total length of 1 @,@ 960 to 2 @,@ 500 km and a visual albedo (pv) greater than 0 @.@ 6 . The most likely shape is a triaxial ellipsoid with approximate dimensions of 2 @,@ 000 x 1 @,@ 500 x 1 @,@ 000 km , with an albedo of 0 @.@ 71 . Observations by the Spitzer Space Telescope give a diameter of 1 @,@ 150 + 250
? 100 km and an albedo of 0 @.@ 84 + 0 @.@ 1
? 0 @.@ 2 , from photometry at infrared wavelengths of 70 ?m . Subsequent light @-@ curve analyses have suggested an equivalent circular diameter of 1 @,@ 450 km . In 2010 an analysis of measurements taken by Herschel Space Telescope together with the older Spitzer Telescope measurements yielded a new estimate of the equivalent diameter of Haumea ? about 1300 km . These independent size estimates overlap at an average geometric mean diameter of roughly 1 @,@ 400 km . This makes Haumea one of the largest trans @-@ Neptunian objects discovered ,

smaller than Eris , Pluto , probably Makemake , and possibly 2007 OR10 , and larger than Sedna , Quaoar , and Orcus .

= = = Surface = = =

In 2005 , the Gemini and Keck telescopes obtained spectra of Haumea which showed strong crystalline water ice features similar to the surface of Pluto 's moon Charon . This is peculiar , because crystalline ice forms at temperatures above 110 K , whereas Haumea 's surface temperature is below 50 K , a temperature at which amorphous ice is formed . In addition , the structure of crystalline ice is unstable under the constant rain of cosmic rays and energetic particles from the Sun that strike trans @-@ Neptunian objects . The timescale for the crystalline ice to revert to amorphous ice under this bombardment is on the order of ten million years , yet trans @-@ Neptunian objects have been in their present cold @-@ temperature locations for timescales of billions of years . Radiation damage should also redden and darken the surface of trans @-@ Neptunian objects where the common surface materials of organic ices and tholin @-@ like compounds are present , as is the case with Pluto . Therefore , the spectra and colour suggest Haumea and its family members have undergone recent resurfacing that produced fresh ice . However , no plausible resurfacing mechanism has been suggested .

Haumea is as bright as snow , with an albedo in the range of 0 @.@ 6 ? 0 @.@ 8 , consistent with crystalline ice . Other large TNOs such as Eris appear to have albedos as high or higher . Best @-@ fit modeling of the surface spectra suggested that 66 % to 80 % of the Haumean surface appears to be pure crystalline water ice , with one contributor to the high albedo possibly hydrogen cyanide or phyllosilicate clays . Inorganic cyanide salts such as copper potassium cyanide may also be present .

However , further studies of the visible and near infrared spectra suggest a homogeneous surface covered by an intimate 1 : 1 mixture of amorphous and crystalline ice , together with no more than 8 % organics . The absence of ammonia hydrate excludes cryovolcanism and the observations confirm that the collisional event must have happened more than 100 million years ago , in agreement with the dynamic studies . The absence of measurable methane in the spectra of Haumea is consistent with a warm collisional history that would have removed such volatiles , in contrast to Makemake .

In addition to the large fluctuations in Haumea 's light curve due to the body 's shape , which affect all colours equally , smaller independent colour variations seen in both visible and near @-@ infrared wavelengths show a region on the surface that differs both in colour and in albedo . More specifically , a large dark red area on Haumea 's bright white surface was seen in September 2009 , possibly an impact feature , which indicates an area rich in minerals and organic (carbon @-@ rich) compounds , or possibly a higher proportion of crystalline ice . Thus Haumea may have a mottled surface reminiscent of Pluto , if not as extreme .

= = Moons = =

Two small satellites have been discovered orbiting Haumea , (136108) Haumea I Hi?iaka and (136108) Haumea II Namaka . Brown 's team discovered both in 2005 , through observations of Haumea using the W.M. Keck Observatory .

Hi?iaka , at first nicknamed " Rudolph " by the Caltech team , was discovered January 26 , 2005 . It is the outer and , at roughly 310 km in diameter , the larger and brighter of the two , and orbits Haumea in a nearly circular path every 49 days . Strong absorption features at 1 @.@ 5 and 2 micrometres in the infrared spectrum are consistent with nearly pure crystalline water ice covering much of the surface . The unusual spectrum , along with similar absorption lines on Haumea , led Brown and colleagues to conclude that capture was an unlikely model for the system 's formation , and that the Haumean moons must be fragments of Haumea itself .

Namaka , the smaller , inner satellite of Haumea , was discovered on June 30 , 2005 , and nicknamed " Blitzen " . It is a tenth the mass of Hi?iaka , orbits Haumea in 18 days in a highly

elliptical , non @-@ Keplerian orbit , and as of 2008 is inclined 13 ° from the larger moon , which perturbs its orbit . The relatively large eccentricities together with the mutual inclination of the orbits of the satellites are unexpected as they should have been damped by the tidal effects . A relatively recent passage by a 3 : 1 resonance might explain the current excited orbits of the Haumean moons .

At present , the orbits of the Haumean moons appear almost exactly edge @-@ on from Earth , with Namaka periodically occulting Haumea . Observation of such transits would provide precise information on the size and shape of Haumea and its moons , as happened in the late 1980s with Pluto and Charon . The tiny change in brightness of the system during these occultations will require at least a medium @-@ aperture professional telescope for detection . Hi?iaka last occulted Haumea in 1999 , a few years before discovery , and will not do so again for some 130 years . However , in a situation unique among regular satellites , Namaka 's orbit is being greatly torqued by Hi?iaka , preserving the viewing angle of Namaka ? Haumea transits for several more years .

= = Collisional family = =

Haumea is the largest member of its collisional family , a group of astronomical objects with similar physical and orbital characteristics thought to have formed when a larger progenitor was shattered by an impact . This family is the first to be identified among TNOs and includes ? beside Haumea and its moons ? (55636) 2002 TX300 (? 364 km) , (24835) 1995 SM55 (? 174 km) , (19308) 1996 TO66 (? 200 km) , (120178) 2003 OP32 (? 230 km) , and (145453) 2005 RR43 (? 252 km) . Brown and colleagues proposed that the family were a direct product of the impact that removed Haumea 's ice mantle , but a second proposal suggests a more complicated origin : that the material ejected in the initial collision instead coalesced into a large moon of Haumea , which was later shattered in a second collision , dispersing its shards outwards . This second scenario appears to produce a dispersion of velocities for the fragments that is more closely matched to the measured velocity dispersion of the family members .

The presence of the collisional family could imply that Haumea and its " offspring " might have originated in the scattered disc . In today 's sparsely populated Kuiper belt , the chance of such a collision occurring over the age of the Solar System is less than 0 @.@ 1 percent . The family could not have formed in the denser primordial Kuiper belt because such a close @-@ knit group would have been disrupted by Neptune 's migration into the belt ? the believed cause of the belt 's current low density . Therefore , it appears likely that the dynamic scattered disc region , in which the possibility of such a collision is far higher , is the place of origin for the object that generated Haumea and its kin .

Because it would have taken at least a billion years for the group to have diffused as far as it has , the collision which created the Haumea family is believed to have occurred very early in the Solar System 's history .

= = Exploration = =

It was calculated that a flyby mission to Haumea could take 14 @.@ 25 years using a Jupiter gravity assist , based on a launch date of 25 September 2025 . Haumea would be 48 @.@ 18 AU from the Sun when the spacecraft arrives . A flight time of 16 @.@ 45 years can be achieved with launch dates on 1 November 2026 , 23 September 2037 and 29 October 2038 . Haumea could become a target for an exploration missions , and an example of this work is a preliminary study on a probe to Haumea and its moons (at 35 ? 51 AU) . Probe mass , power source , and propulsion systems are key technology areas for this type of mission .