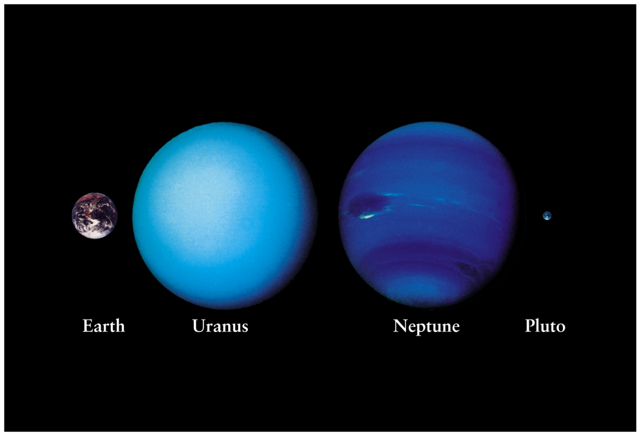
Pluto



Discovery of Pluto

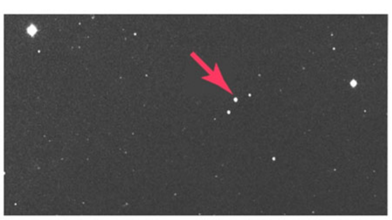
Pluto was discovered through a systematic search, not (like Neptune) as the result of a position calculated from gravitational theory. Nevertheless, the history of the search for Pluto began with indications of departures of Uranus and Neptune.

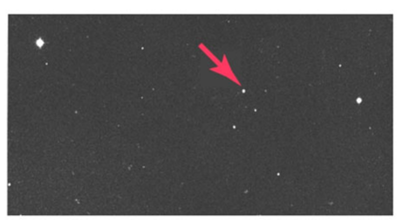
Percival Lowell and his contemporaries based their calculations on the remaining irregularities of the motion of Uranus. Many solutions were derived.

Clyde Tombaugh

Discovery Photographs

Lowell (and observatory) searched from 1906 until his death in 1916. Then Lowell’s brother donated a telescope that covered large area of the sky. In February 1930, Clyde Tombaugh, comparing photographs made on January 23 and 29 of that year, found an object whose motion appeared to be right. It was within 6^{o} of the position Lowell predicted, and the announcement was made on Lowell’s birthday.





Pluto’s Orbital Motion

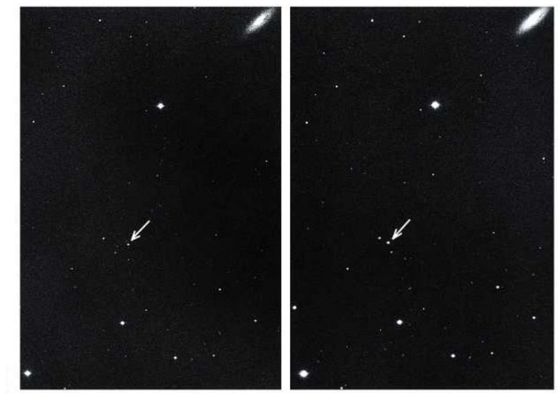
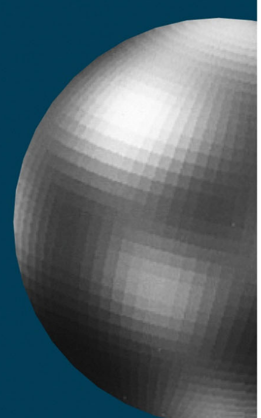


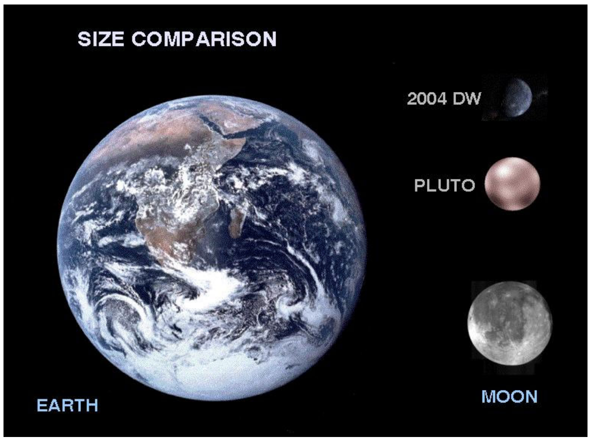
table 16-5 Pluto Data

Average distance from Sun:	39.537 AU = 5.915×10^9 km
Maximum distance from Sun:	49.425 AU = 7.394×10^9 km
Minimum distance from Sun:	29.649 AU = 4.435×10^9 km
Eccentricity of orbit:	0.2501
Average orbital speed:	4.7 km/s
Orbital period:	248.60 years
Rotation period:	6.387 days
Inclination of equator to orbit:	122.52°
Inclination of orbit to ecliptic:	17.146°
Diameter:	about 2300 km = 0.18 Earth diameter
Mass:	1.3×10^{22} kg = 0.0021 Earth mass
Average density:	about 1900 kg/m^3
Escape speed:	1.2 km/s
Surface gravity (Earth = 1):	0.07
Albedo:	0.5
Average surface temperature:	−233°C = −387°F = 40 K



(Alan Stern, Southwest Research Institute; Marc Buie, Lowell Observatory; NASA; and ESA)

Pluto



Pluto is neither a Jovian planet nor a terrestrial one. It is a small object, perhaps one of many such bodies that once orbited the Sun beyond the giant planets.

Because it is so small, some have even suggested that Pluto should be classified as an asteroid rather than one of the major planets.

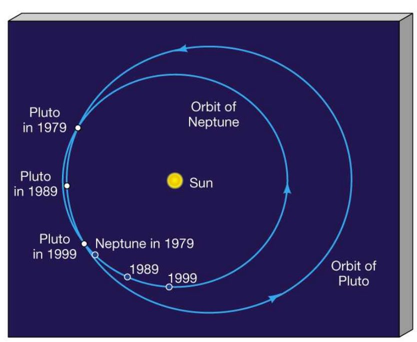
It is now classified as a

Dwarf Planet.

Pluto's Orbit

Pluto's orbit has the highest inclination to the ecliptic (17°) of any "planet" and also has the largest eccentricity (0.248). Its mean distance from the Sun is 40 AU, or 5.9 billion km, but its perihelion distance is under 4.5 billion km, which is within the orbit of Neptune.

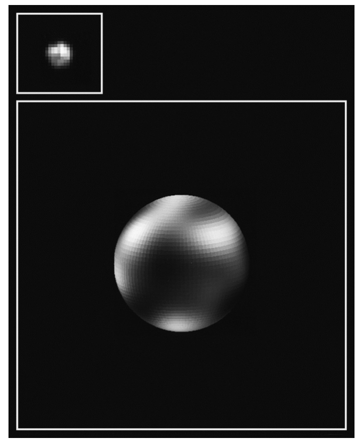
Pluto passed its perihelion in 1989, and it remained inside the orbit of Neptune until 1999. Even though the orbits of these two cross, there is no danger of collision; because of its high inclination, Pluto's orbit clears Neptune's by 385 million km.



Pluto's Orbit

Pluto completes its orbit in 248.6 years. Since its discovery in 1930, the planet has traversed a little more than one-third of its long path around the Sun.

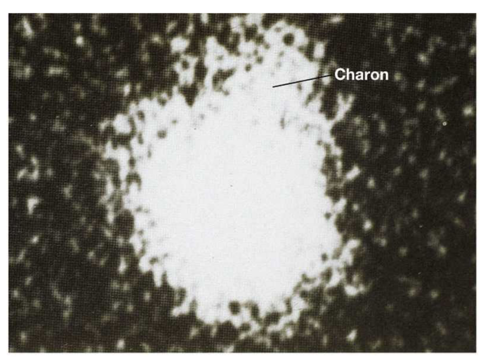
This is the best Hubble picture.



Charon Detected

Pluto's moon **Charon** ("Sharon") was discovered in 1978 by James Christy.

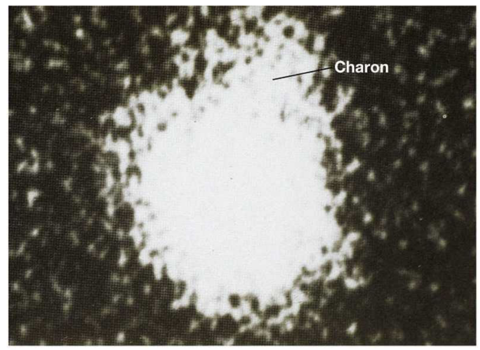
Asymmetrical images were seen to have changed with time. All of the photographic observations could be fit to a period of 6.387 days. This is the same as Pluto's rotation period.



Charon Detected

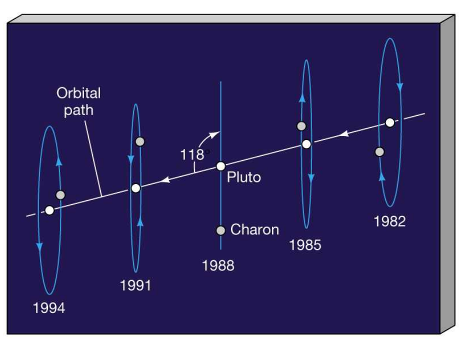
Because the orbital and rotation periods are the same, that means Pluto keeps the same side always turned toward Charon.

Since the moon also surely has the same rotation period, this is the only planet-moon system in which both members are tidally locked.

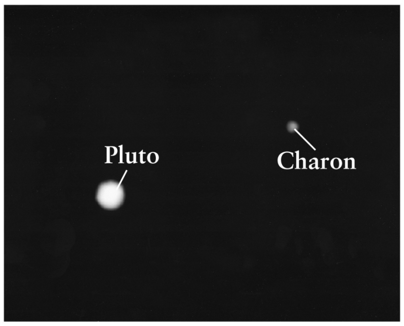


Orbital Planes

The exact nature of the orbit of Pluto's moon was not confirmed until 1985, when the system had turned to the point at which the moon and the planet began to occult each other. These occultation observations determined that it had a diameter of about 1200 km, more than half the size of Pluto.



Pluto and Charon



Confirmation of the orbit of **Charon** clarified that Pluto's rotation is **retrograde**.

The obliquity of Pluto's rota-tional axis is 112°, similar to that of Uranus.

At present, the equator of Pluto faces approximately toward the Sun, but in about 60 years the pole will nearly point to the Sun.

Mass of Pluto

Remember that the search for Pluto was motivated to explain observed discrepancies in the orbits of Uranus. When Pluto was discovered, it was assumed that it had a mass several times larger than the mass of the Earth, since that is the mass required to account for the apparent perturbations of Uranus. Unfortunately, the large mass was not consistent with Pluto's small size, unless it had an unreasonably large density.

The discovery of **Charon** finally helped resolve the problem by providing a means to measure the mass of Pluto accurately. Pluto's mass is 1/400 the mass of the Earth, insufficient to have caused observable perturbations in Uranus or Neptune.

Density of Pluto

Before New Horizons, the diameter of Pluto was estimated to be 2100 km, only 60% as large as the Moon. From the diameter and mass, the density is 2.1 g/cm^3, higher than that of most of the giant-planet satellites, but still suggesting the presence of water ice.

Calculations indicate about 75% rock & metal and 25% water ice.

Relative Sizes

This graphic presents a view of Pluto and Charon as they would appear if placed slightly above Earth's surface and viewed from a great distance.

Recent measurements obtained by New Horizons indicate that Pluto has a diameter of 2370 km, 18.5% that of Earth's, while Charon has a diameter of 1208 km, 9.5% that of Earth's.

Pluto's Surface

Pluto's surface is highly reflective, and its spectrum indicates the presence of **methane ice**. The surface temperature ranges from about 50 K near aphelion to about 60 K near perihelion, resulting in partial evaporation of methane ice to generate an atmosphere.

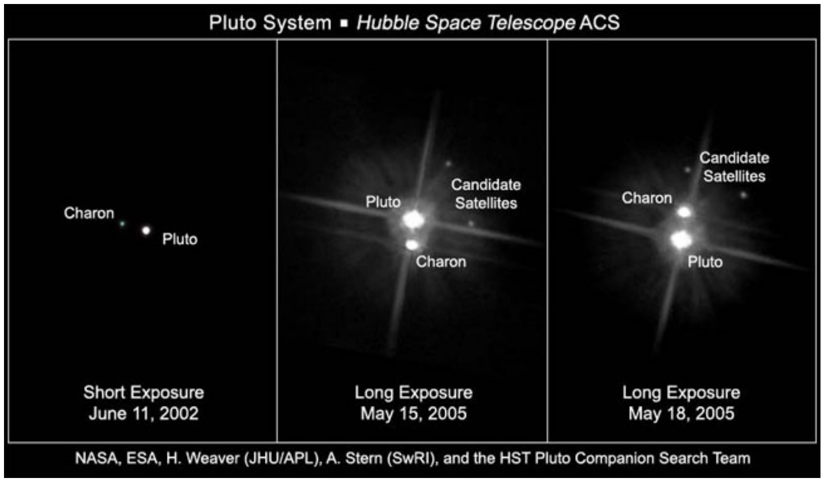
Pluto is now in its warmest period, and its atmosphere is accordingly near maximum size and density. Observations of a stellar occultation suggest that the surface pressure is near 1/10000 bar and that the atmosphere consists of a mixture of CH_4 and N_2 gases.

Charon's Surface

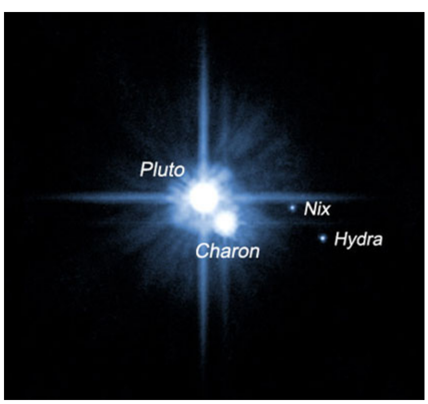
Charon is more than half as large as Pluto − the largest moon in the Solar System *relative to the diameter of its primary planet*.

Charon's surface shows the spectral signature of **water ice** rather than methane ice. Perhaps it once contained methane, but with its smaller surface gravity Charon was not able to retain this gas. Water ice, in contrast, remains tightly frozen at this distance from the Sun, and Charon therefore does not develop an atmosphere near perihelion, as Pluto does.

Two New Moons



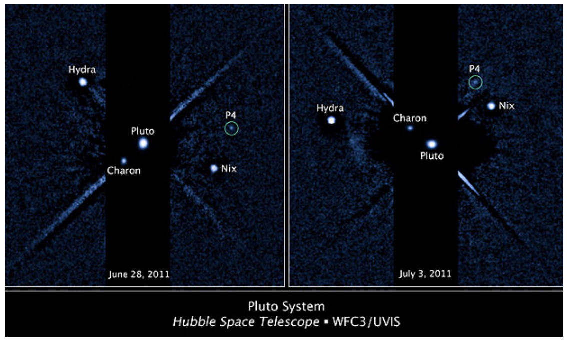
Names of the New Moons



In mythology, Nyx is the goddess of the night. Among her many offspring was Charon, the boatman who ferried the dead across the river Styx into the underworld. Because asteroid 3908 already bears the Greek name Nyx, the IAU changed Nyx to its Egyptian equivalent, **Nix**.

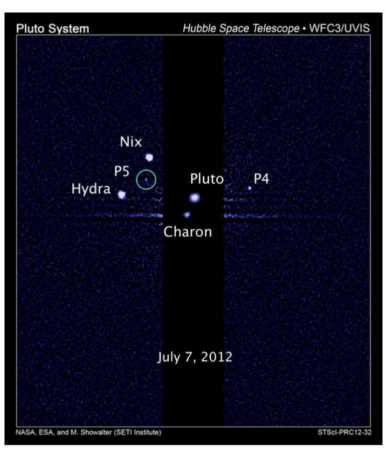
The mythological Hydra was a nine-headed serpent with poisonous blood. The **Hydra** had its den at the entrance to Hades, where Pluto and his wife Persephone were supposed to have entered the Underworld.

A Fourth New Moon



The new moon **Kerberos** is the smallest discovered around Pluto. It has an estimated diameter of 8 to 21 miles (13 to 34 km). By comparison, Charon, Pluto's largest moon, is 648 miles (1,043 km) across, and the other moons, Nix and Hydra, are in the range of 20 to 70 miles in diameter (32 to 113 km). Discovered July 20, 2011.

A Fifth New Moon



This image, taken by the Hubble Space Telescope, shows five moons orbiting Pluto.

The **green** circle marks the newly discovered moon, first designated as P5 but now named as **Styx**, as photographed by Hubble's Wide Field Camera 3 on July 7, 2012.

Pluto and Charon

Pluto and Charon are shown in a composite of natural-color images, which is the highest-resolution color image of the pair yet returned to Earth. It was taken about five hours before closest approach to Pluto, from a range of 150,000 miles (250,000 km).

Pluto and Charon

The image highlights the contrasting appearance of the two worlds: Charon is mostly gray, with a dark reddish polar cap, while Pluto shows a wide variety of subtle color variations, including yellowish patches on the north polar cap and subtly contrasting colors for the two halves of Pluto's "heart", now informally named **Tombaugh Regio** (Tombaugh Region), seen in the upper right quadrant of the image.

Pluto and Charon

This image highlights the striking differences between Pluto and Charon. The color and brightness of both worlds have been processed identically to allow direct comparison of their surface properties, and to highlight the similarity between Charon's polar red terrain and Pluto's equatorial red terrain.

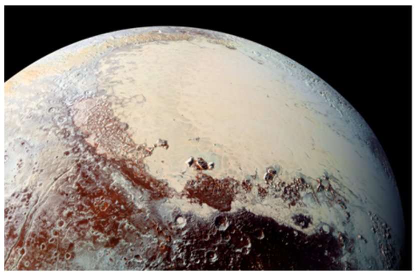
Pluto and Charon are shown with approximately correct relative sizes, but their true separation is not to scale.

Pluto's Surface

Pluto's surface sports a remarkable range of subtle colors, enhanced in this view to a rainbow of pale blues, yellows, oranges, and deep reds.

Many landforms have their own distinct colors, telling a complex geological and climate-logical story that scientists have only just begun to decode. The image resolves details and colors on scales as small as 0.8 miles.

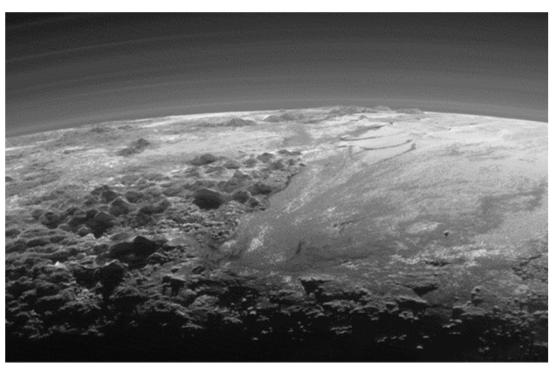
Pluto’s Surface



The bright expanse is the western lobe of the “heart,” informally known as Tombaugh Regio.

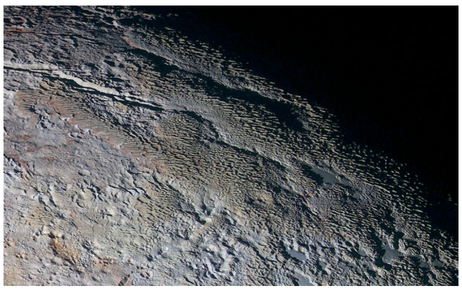
The white lobe, informally called **Sputnik Planum**, has been found to be rich in nitrogen, carbon monoxide, and methane ices.

Pluto’s Surface



The smooth expanse on the right is flanked to the left by rugged mountains up to 2 miles (3.5 km) high. The backlighting highlights more than a dozen layers of haze in Pluto’s tenuous but distended atmosphere.

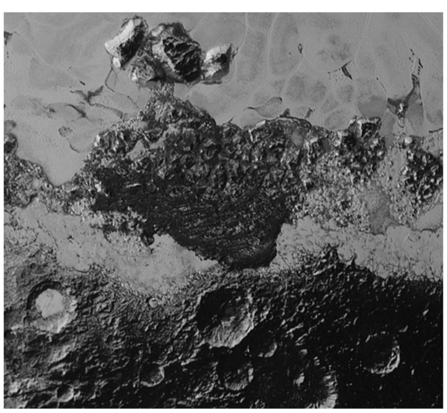
Pluto Closeup



In this extended color image, rounded and bizarrely textured mountains, informally named the **Tartarus Dorsa**, rise up along Pluto's day-night terminator and show intricate but puzzling patterns of blue-gray ridges and reddish material in between.

This view, roughly 330 miles (530 km) across, resolves details and colors on scales as small as 0.8 miles (1.3 km).

Pluto Closeup



This 220-mile (350-km) wide view of Pluto shows the diversity of surface reflectivities and geological landforms.

The image includes dark, ancient heavily cratered terrain; bright, smooth geologically young terrain; assembled masses of mountains; and an enigmatic field of dark, aligned ridges that resemble dunes.

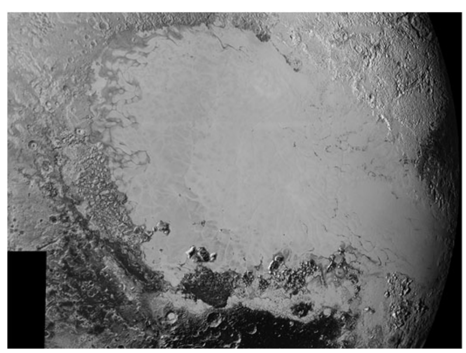
The smallest visible features are 0.5 miles (0.8 km) in size.

Pluto Closeup

In this 75-mile (120-km) section, the textured surface of the plain surrounds two isolated ice mountains.

Pluto Closeup

The image is dominated by the informally-named icy plain Sputnik Planum, the smooth, bright region across the center. This image also features a tremendous variety of other landscapes surrounding Sputnik. The smallest visible ones are 0.5 miles (0.8 km) in size, and the mosaic covers a region roughly 1,000 miles (1600 km) wide.



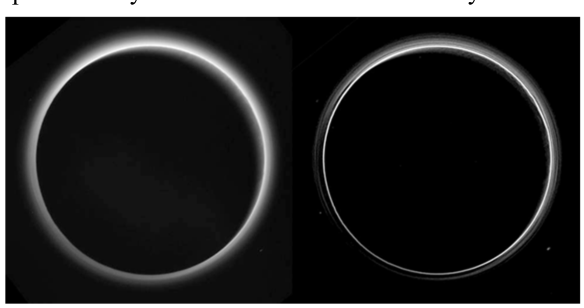
Pluto’s Atmosphere

Pluto’s haze layer shows its blue color in this picture. The high-altitude haze is thought to be similar in nature to that seen at Saturn’s moon Titan.

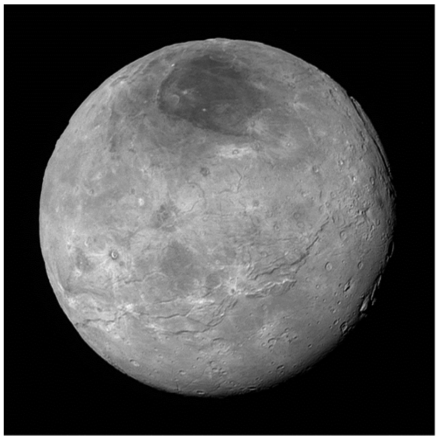
The source of both hazes likely involves sunlight-initiated chemical reactions of nitrogen and methane, leading to relatively small, soot-like particles that grow as they settle toward the surface.

Pluto’s Atmosphere

Two versions of Pluto’s haze layers, taken ~16 hours after close approach. The left version has had only minor processing, while the right one has been specially processed to reveal a large number of discrete haze layers in the atmosphere. In the left image, faint surface details on the narrow sunlit crescent are seen through the haze, and subtle parallel streaks in the haze may be crepuscular rays – shadows cast on the haze by mountains.

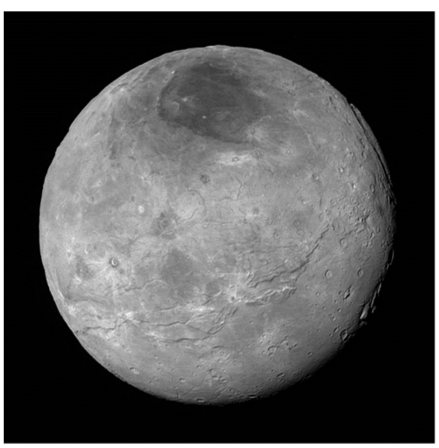


Charon’s Surface



Charon, 750 miles (1,200 km) in diameter, displays a complex geological history, including tectonic fracturing; relatively smooth, fractured plains in the lower right; several enigmatic mountains surrounded by sunken terrain features on the right side; and heavily cratered regions in the center and upper left portion of the disk.

Charon’s Surface



There are also complex reflectivity patterns on Charon’s surface, including bright and dark crater rays, and the conspicuous dark north polar region at the top of the image. The smallest visible features are 2.9 miles (4.6 km) in size.

Charon's Surface

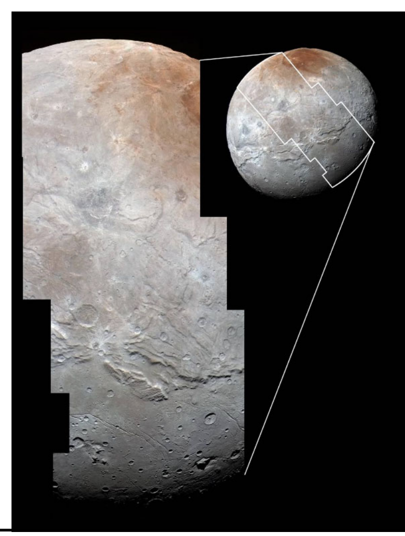
This is a high-resolution enhanced color view of Charon. The colors are processed to best highlight the variation of surface properties. Charon's color palette is not as diverse as Pluto's; most striking is the reddish north (top) polar region, informally named **Mordor Macula**. Charon is 754 miles (1,214 km) across; this image resolves details as small as 1.8 miles (2.9 km).

Charon's Surface

High-resolution images of the Pluto-facing hemisphere of Charon, reveal details of a belt of fractures and canyons just north of the equator.

This canyon system stretches more than 1,000 miles (1,600 km) across the entire face of Charon and likely around onto Charon's far side.

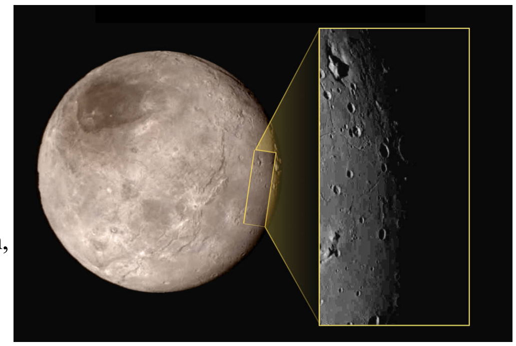
Four times as long as the Grand Canyon, and twice as deep, these faults and canyons indicate a titanic geological upheaval in its past.



Charon Closeup

This image of an area on Charon has a captivating feature – a depression with a peak in the middle, shown here in the upper left corner of the inset.

The image shows an area ~240 miles (390 km) from top to bottom, including few visible craters. “The most intriguing feature is a large mountain sitting in a moat,”



Pluto’s Moons

Family Portrait of Pluto’s Moons: This composite image shows a sliver of Pluto’s large moon, Charon, and all four of Pluto’s small moons, as resolved by the New Horizons spacecraft. All the moons are displayed with a common intensity stretch and spatial scale (see scale bar).

What is a Planet?

Question: What is the definition of Planet?

The following slides are taken from an article by the discoverer of Sedna.

http://www.gps.caltech.edu/~mbrown/sedna/#planets

IAU Decision

The IAU members gathered at the 2006 General Assembly agreed that a "planet" is defined as 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.

IAU Decision

This means that the Solar System consists of **eight planets**:
Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune.

A new class of objects called "dwarf planets" was also decided.

It was agreed that "planets" and "dwarf planets" are two distinct classes of objects.

Dwarf Planet

A **dwarf planet** is a celestial body orbiting the Sun that is massive enough to be rounded by its own gravity but which has not cleared its neighboring region of planetesimals and is not a satellite.

The term dwarf planet was adopted in 2006 as part of a three-way categorization of bodies orbiting the Sun. This classification states that bodies large enough to have cleared the neighborhood of their orbit are defined as planets, while those that are not massive enough to be rounded by their own gravity are defined as small solar system bodies. Dwarf planets come in between.

The IAU currently recognizes five dwarf planets — Ceres, Pluto, Haumea, Makemake, and Eris.

Plutoids

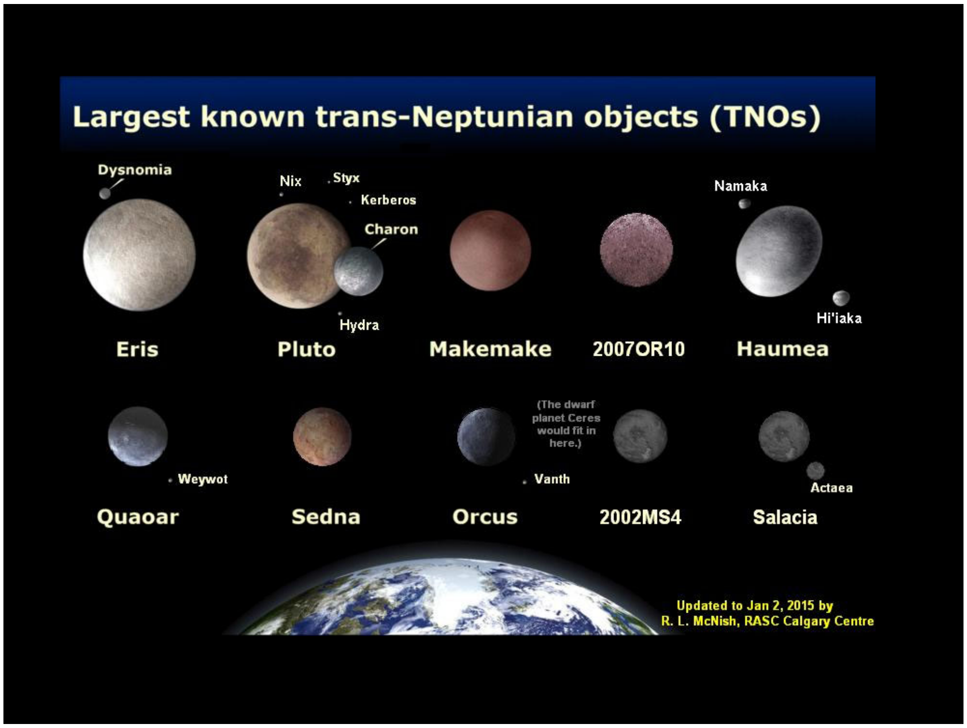
A **plutoid** is a trans-Neptunian dwarf planet. The IAU developed this category as a consequence of its 2006 resolution defining the word “planet”. The IAU's formal definition, announced 11 June 2008, is:

Plutoids are bodies in orbit around the Sun at a semi-major axis greater than that of Neptune that have sufficient mass for their self-gravity to overcome rigid body forces so that they assume a hydrostatic equilibrium (near-spherical) shape, and that have not cleared the neighborhood around their orbit. (Satellites of plutoids are not plutoids themselves.)

Accordingly, plutoids can be thought of as the intersection of the set of dwarf planets and the set of trans-Neptunian objects. As of 2008, **Pluto, Eris, Haumea,** and **Makemake** are the only objects classified as plutoids.

Kuiper Belt Objects

There are about 600 known Kuiper Belt Objects, most of which are only about 100 km in diameter, and all of which were discovered since 1992 by different scientists who have been looking for them. It is similar to the Asteroid Belt, but beyond Neptune and contains maybe 100 times more material.


Largest known trans-Neptunian objects (TNOs)
Dysnomia
Nix
Styx
Kerberos
Charon
Hydra
Namaka
Hi'iaka
Eris
Pluto
Makemake
2007OR10
Haumea
(The dwarf planet Ceres would fit in here.)
Weywot
Vanth
Actaea
Quaoar
Sedna
Orcus
2002MS4
Salacia
Updated to Jan 2, 2015 by
R. L. McNish, RASC Calgary Centre