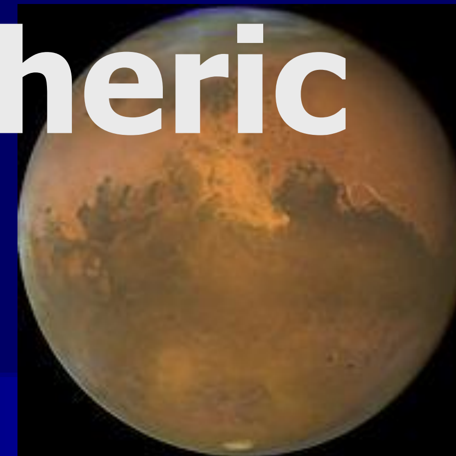
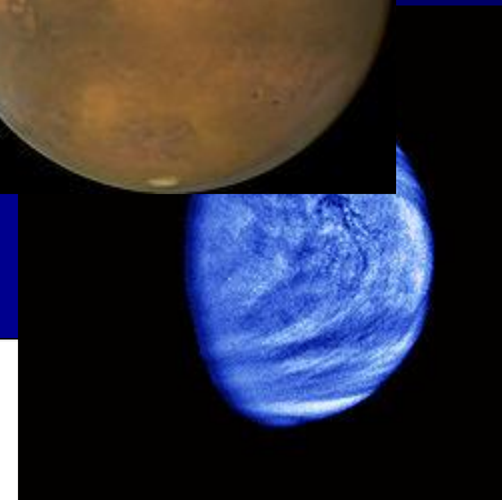
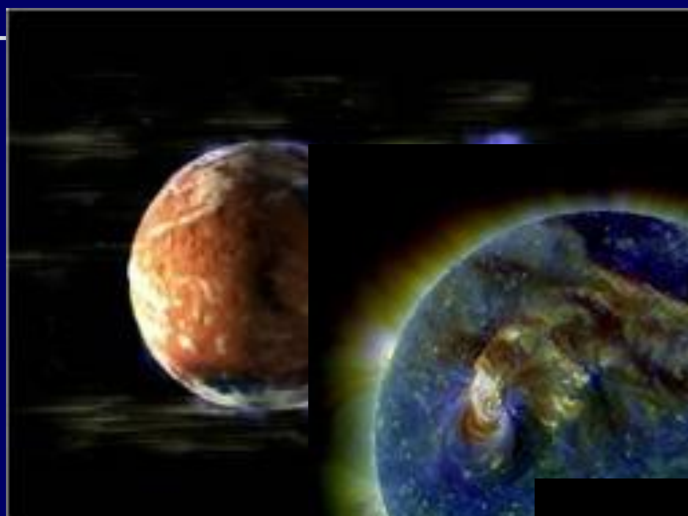
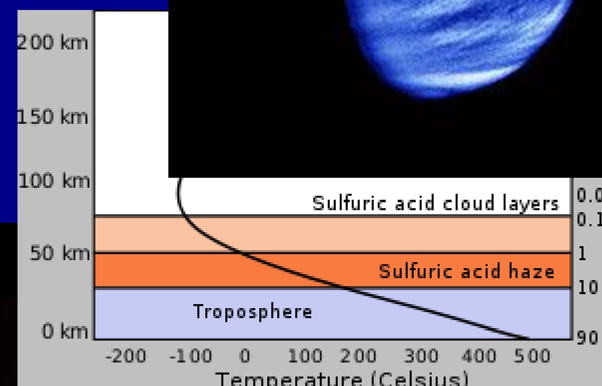
Space & Atmospheric Physics

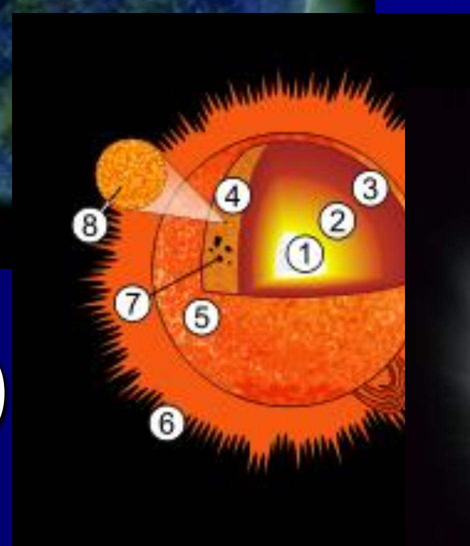
Space & Atmospheric Physics

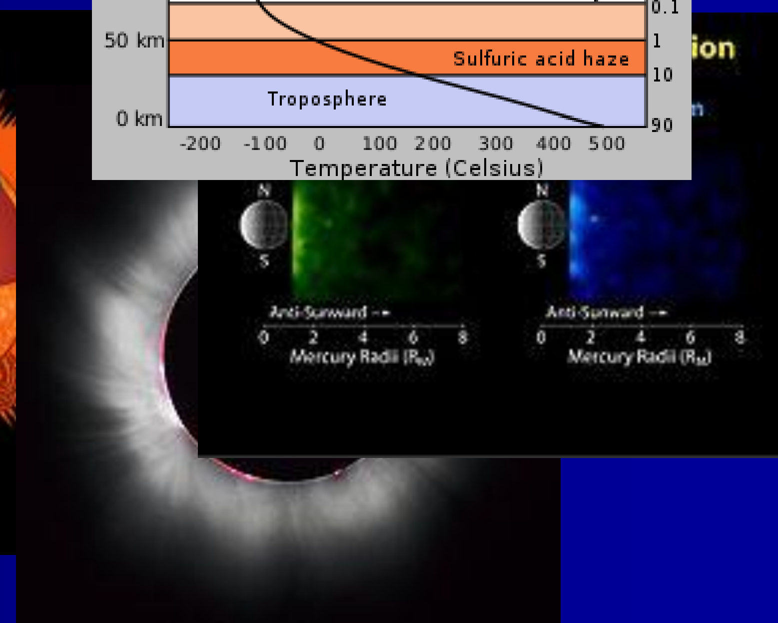












Lecture - 04 (II)

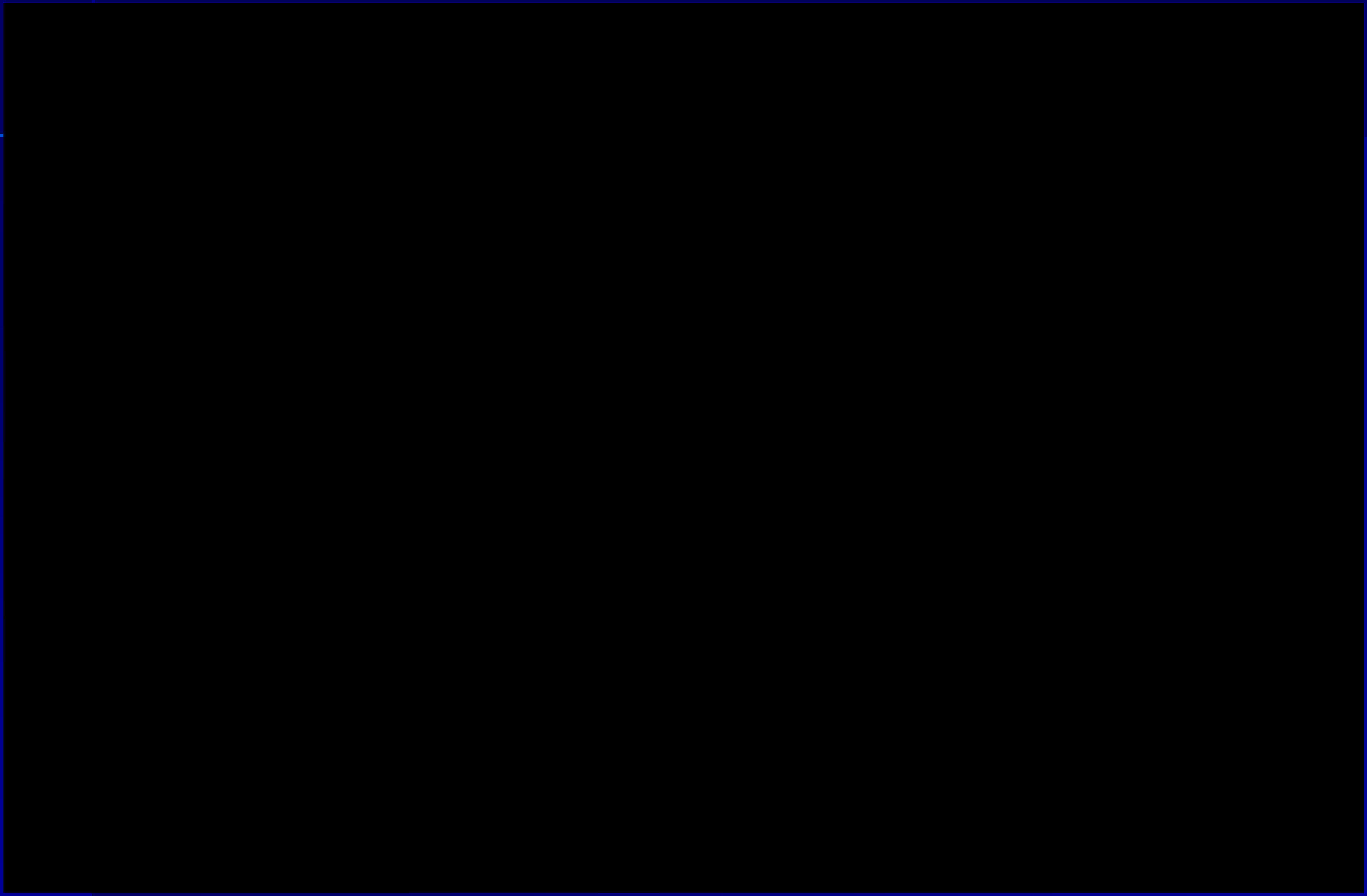
Atmosphere of Pluto

Atmosphere of Pluto

CRIRES model-based computer-generated impression of the Plutonian surface by ESO - L. Calçada, with atmospheric haze, and Charon and the Sun in the sky.

Atmosphere of Pluto

Mountains on Pluto



Atmosphere of Pluto

Pluto's atmosphere consists of a thin envelope of nitrogen, methane, and carbon monoxide gases, which are derived from the ices of these substances on its surface.

Its surface pressure ranges from 6.5 to 24 μbar.

Pluto's elongated orbit is predicted to have a major effect on its atmosphere: as Pluto moves away from the Sun, its atmosphere should gradually freeze out, and fall to the ground.

Atmosphere of Pluto

When Pluto is closer to the Sun, the temperature of Pluto's solid surface increases, causing the ices to sublimate into gas.

This creates an anti-greenhouse effect; much as sweet cools the body as it evaporates from the surface of the skin, this sublimation cools the surface of Pluto.

Pluto's temperature is about 43 K (−230 °C), 10 K colder than would otherwise be expected.

The presence of methane, a powerful greenhouse gas, in Pluto's atmosphere creates a temperature inversion, with average temperatures 36 K warmer 10 km above the surface.

Atmosphere of Pluto

The first evidence of Pluto's atmosphere was found by the Kuiper Airborne Observatory in 1985, from observations of the occultation of a star behind Pluto. When an object with no atmosphere moves in front of a star, the star abruptly disappears; in the case of Pluto, the star dimmed out gradually. From the rate of dimming, the atmospheric pressure was determined to be 0.15 pascal, roughly 1/700,000 that of Earth.

In 2002, the atmospheric pressure was estimated to be 0.3 Pascal, even though Pluto was farther from the Sun than in 1988 and thus should have been colder and had a more rarefied atmosphere.

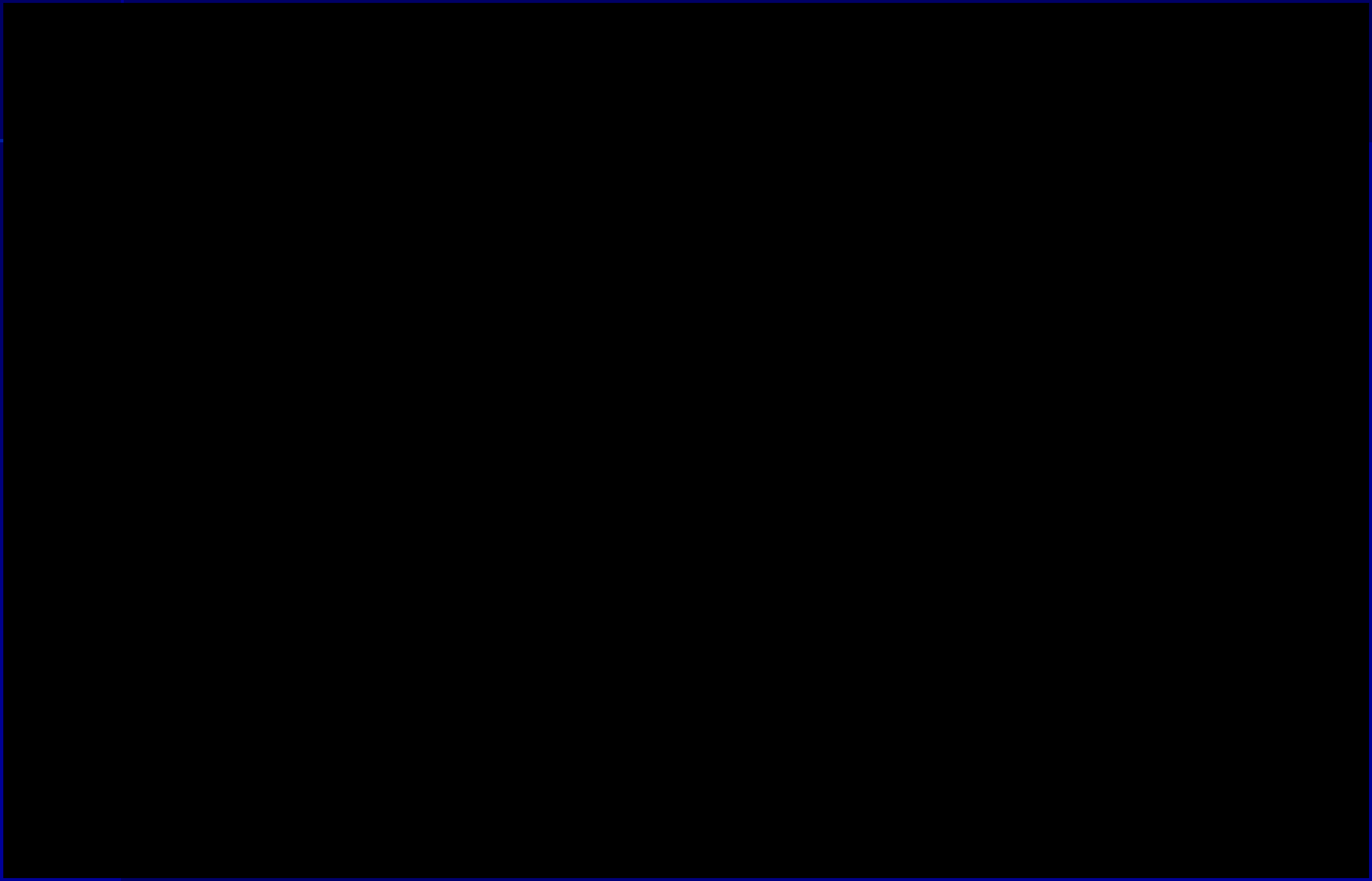
Atmosphere of Pluto

In 2002, the atmospheric pressure was estimated to be 0.3 Pascal, even though Pluto was farther from the Sun than in 1988 and thus should have been colder and had a more rarefied atmosphere.

One explanation for the discrepancy is that in 1987 the south pole of Pluto came out of shadow for the first time in 120 years, causing extra nitrogen to sublimate from the polar cap. It will take decades for the excess nitrogen to condense out of the atmosphere as it freezes onto the north pole's **now permanently dark ice cap**.

Atmosphere of Pluto

New NASA Photo Of Pluto's Atmosphere



Asteroid Belt

Johann Elert Bode (this image is reversed; it was his right eye that was bad)

The Titius-Bode Law is rough rule that predicts the spacing of the planets in the Solar System. The relationship was first pointed out by Johann Titius in 1766 and was formulated as a mathematical expression by J.E. Bode in 1778. It lead Bode to predict the existence of another planet between Mars and Jupiter in what we now recognize as the asteroid belt.

The law relates the mean distances of the planets from the sun to a simple mathematic progression of numbers.

Bode’s law :

The **Titius–Bode law** (sometimes termed just **Bode's law**) is a hypothesis that the bodies in some orbital systems, including the Sun's, orbit at semi-major axes in a function of planetary sequence. The hypothesis correctly predicted the orbits of Mercury to Uranus and Pluto, but failed as a predictor of Neptune's orbit.

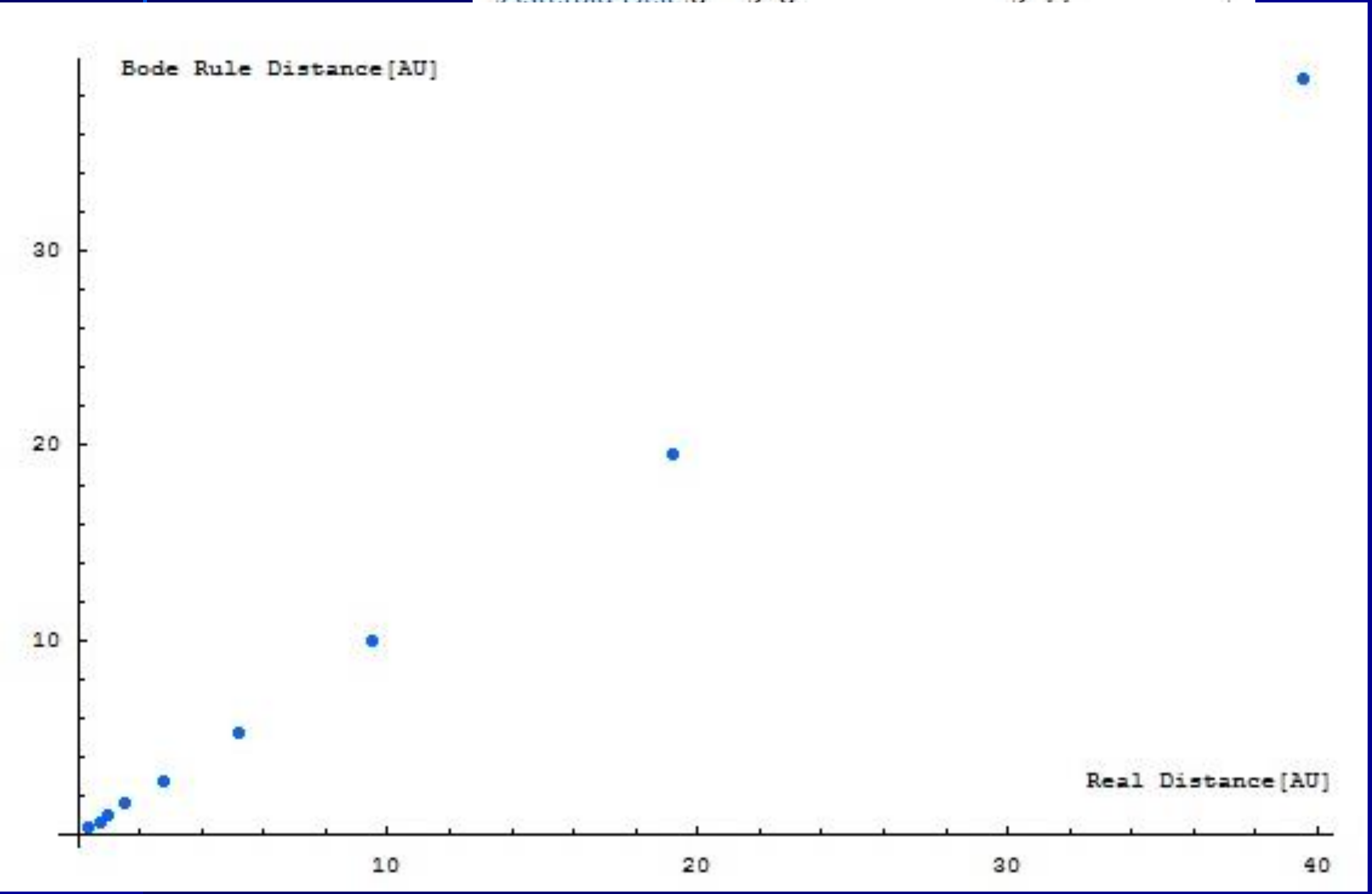
$$d_n = \begin{cases} 0.4 & ; \; n=1 \\ 0.4 + 0.3 \times 2^{n-2} & ; \; n \geq 2 \end{cases}$$

d_n – **Orbital distance (semi-major axis) of n^{th} planet, from the Sun in AU**

$$1\ AU = 149\ 597\ 890\ km$$

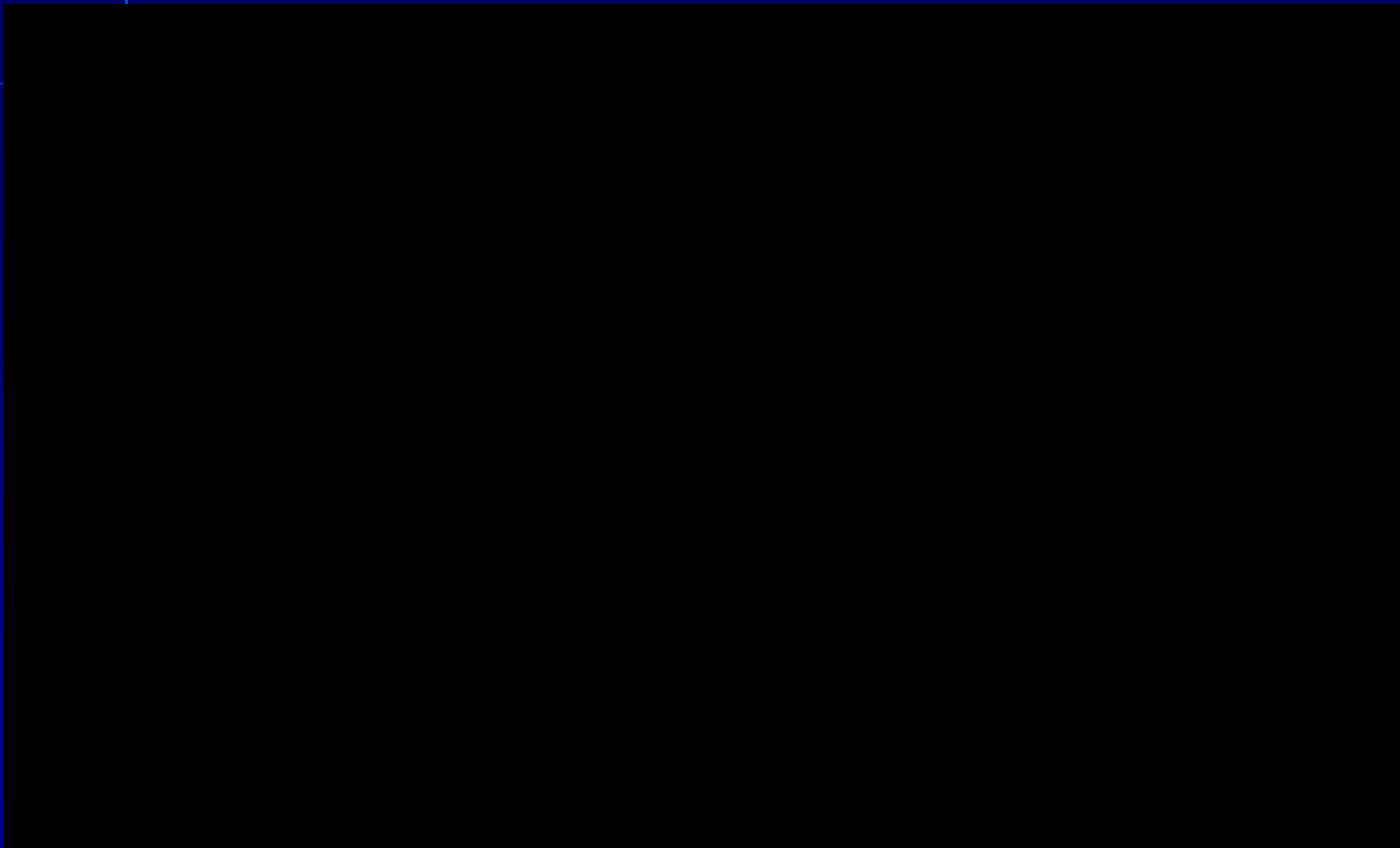
Here are the distances of planets calculated from the original rule and compared with the real ones:

Planet	k	T-B rule distance	Real distance
Mercury	0	0.4	0.39
Venus	1	0.7	0.72
Earth	2	1.0	1.00
Mars	4	1.6	1.52
Asteroid Belt	8	2.8	2.77

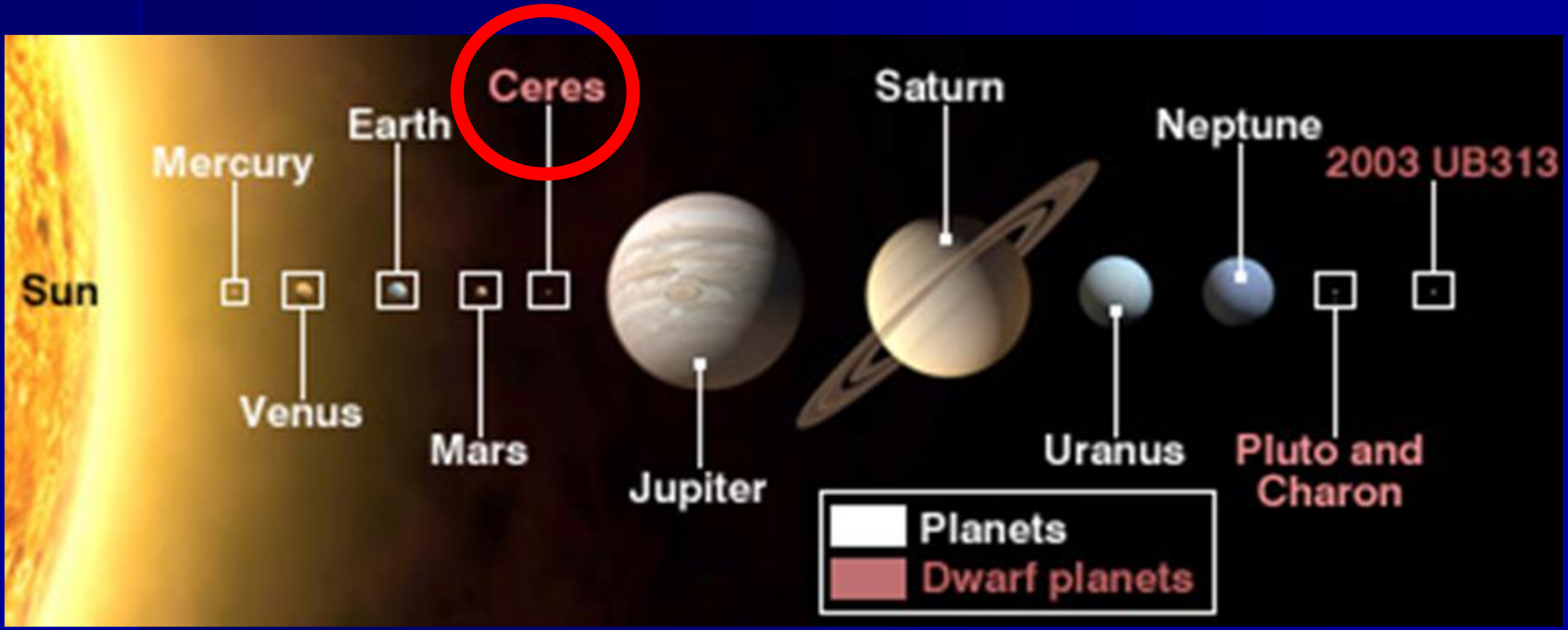


Atmosphere of Ceres

The Asteroid Belt Between Mars and Jupiter

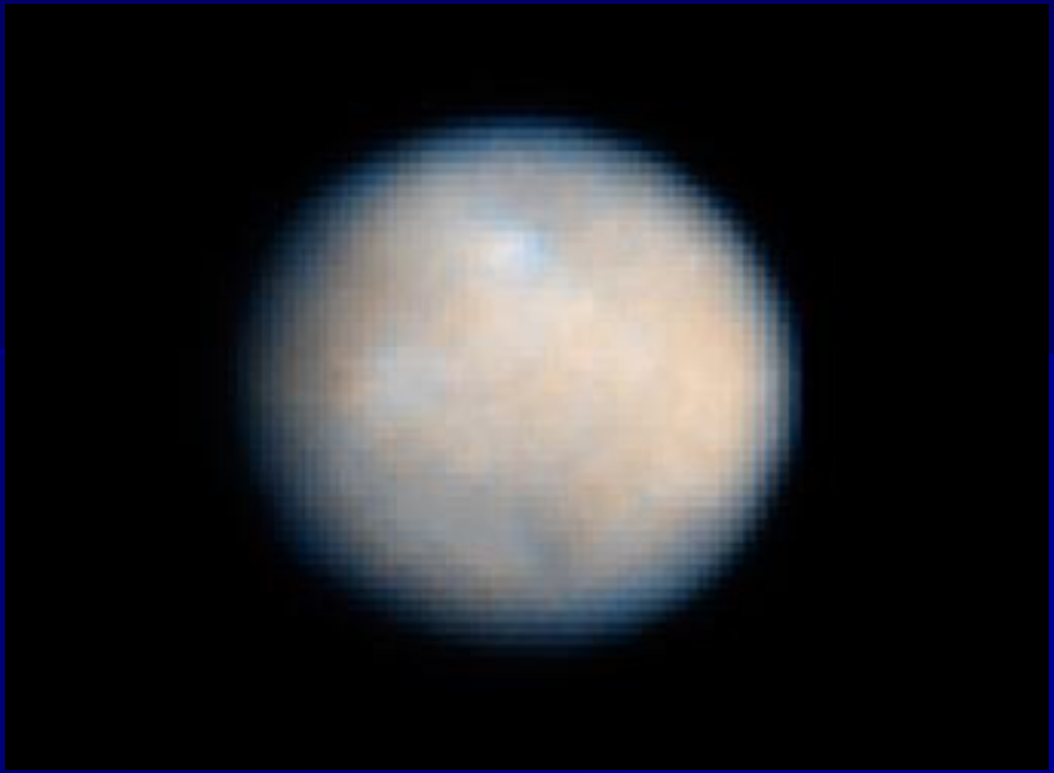


Atmosphere of Ceres



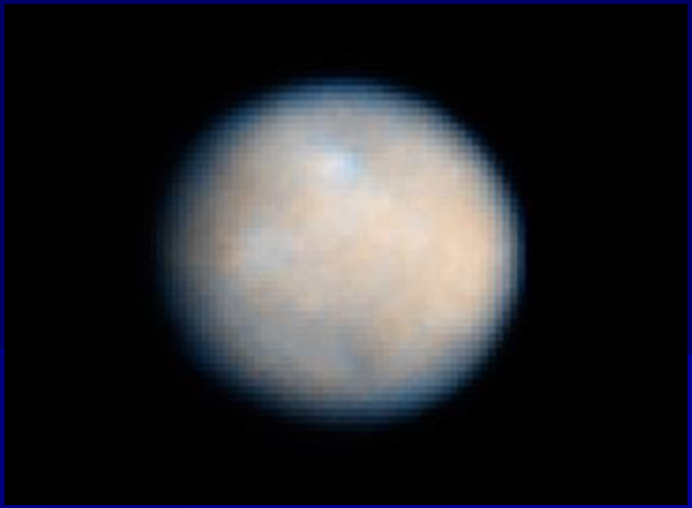
Atmosphere of Ceres

Ceres as seen by Hubble Space Telescope (ACS).



Ceres, is the only dwarf planet - and the largest asteroid - in the inner Solar System. It is a rock–ice body some 950 km (590 mi) in diameter, and though the smallest identified dwarf planet, it constitutes a third of the mass of the asteroid belt. **Discovered on 1 January 1801 by Giuseppe Piazzi.**

Atmosphere of Ceres

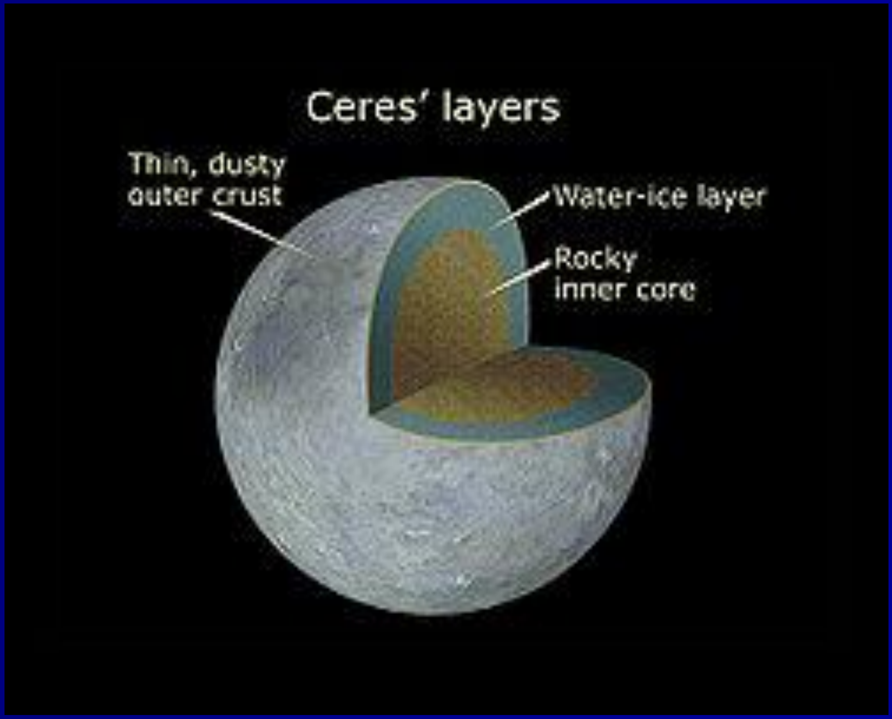


Ceres as seen by Hubble Space Telescope (ACS).

The Cererian surface is probably a mixture of water ice and various hydrated minerals such as carbonates and clays. It appears to be differentiated into a rocky core and icy mantle, and may harbor an ocean of liquid water under its surface.

Atmosphere of Ceres

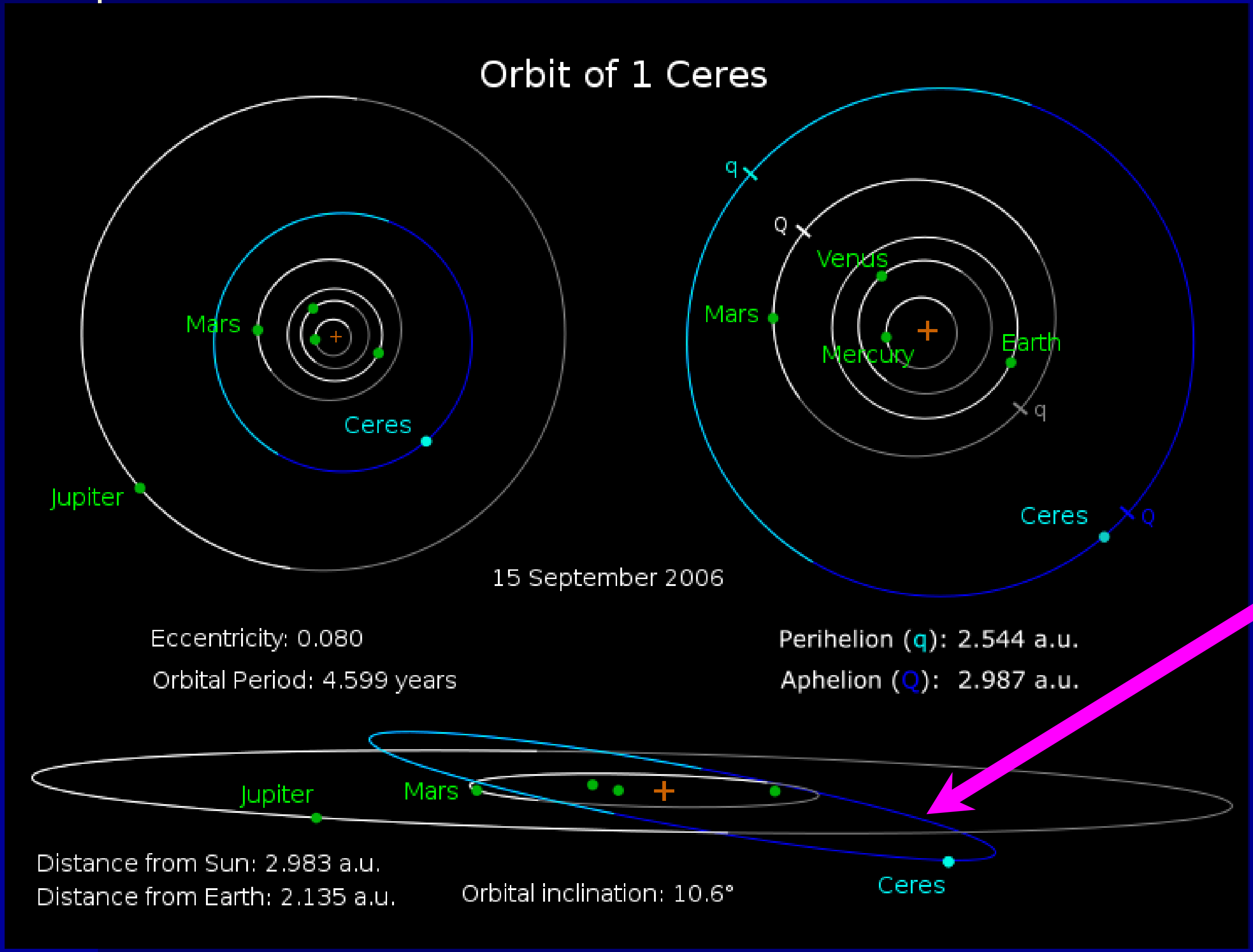
The classification of Ceres has changed more than once and has been the subject of some disagreement. Johann Elert Bode believed Ceres to be the "missing planet" he had proposed to exist between Mars and Jupiter, at a distance of 419 million km (2.8 AU) from the Sun.



Atmosphere of Ceres

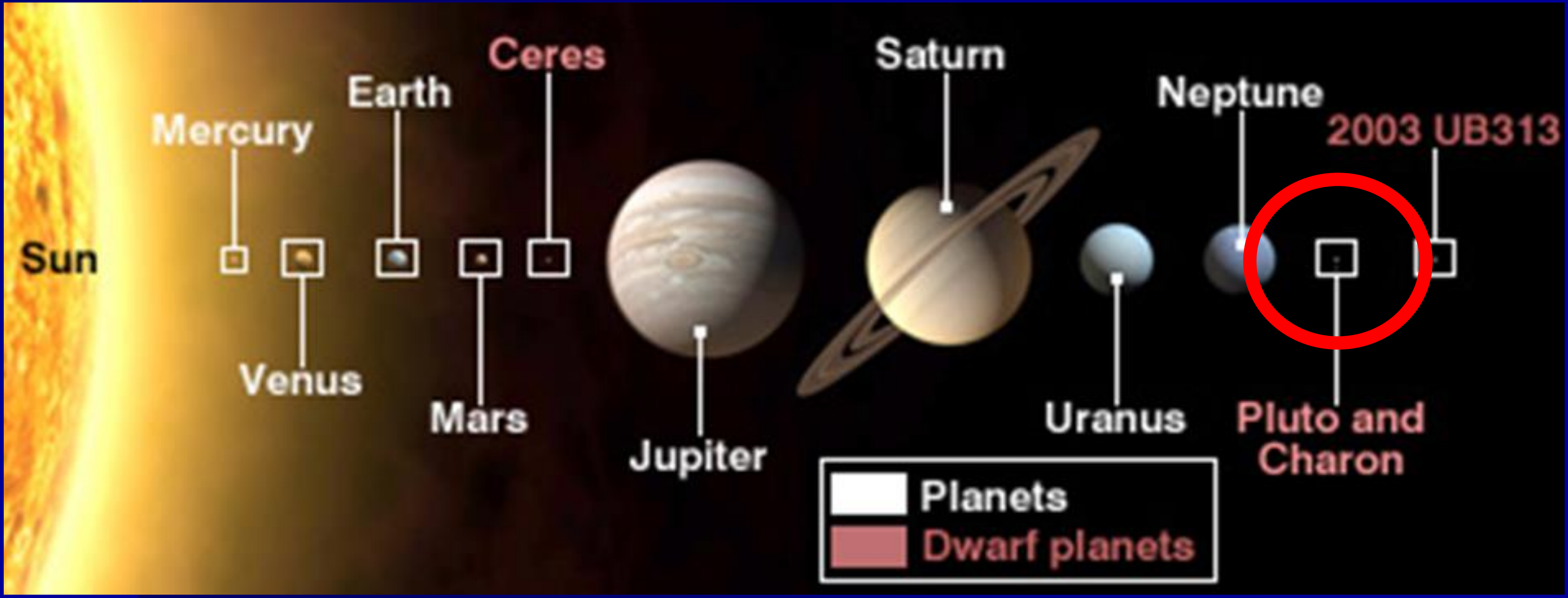
Atmosphere

There are indications that Ceres may have a weak atmosphere and water frost on the surface.



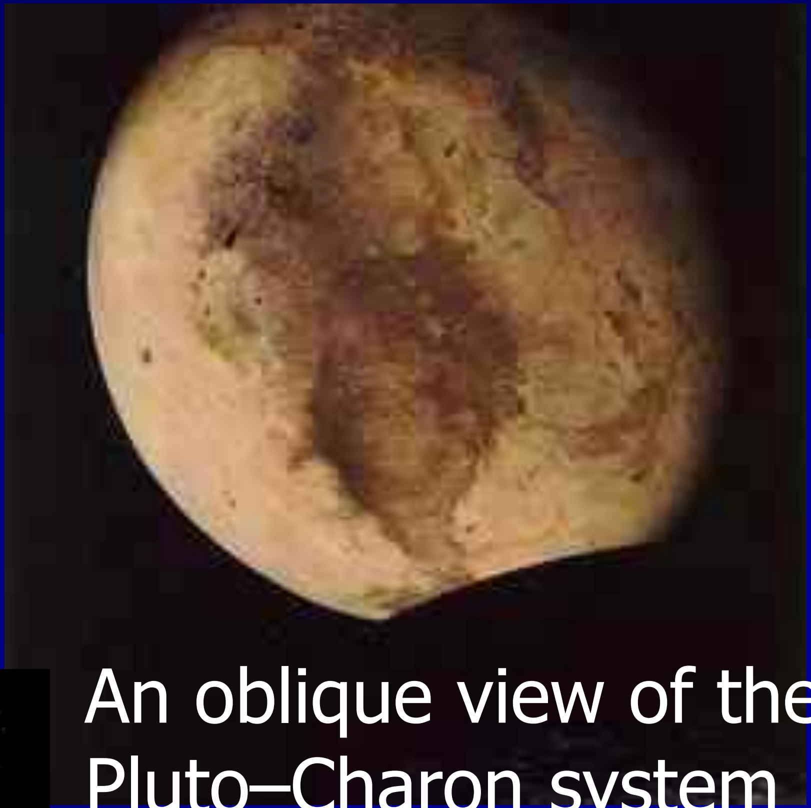
Orbit of Ceres

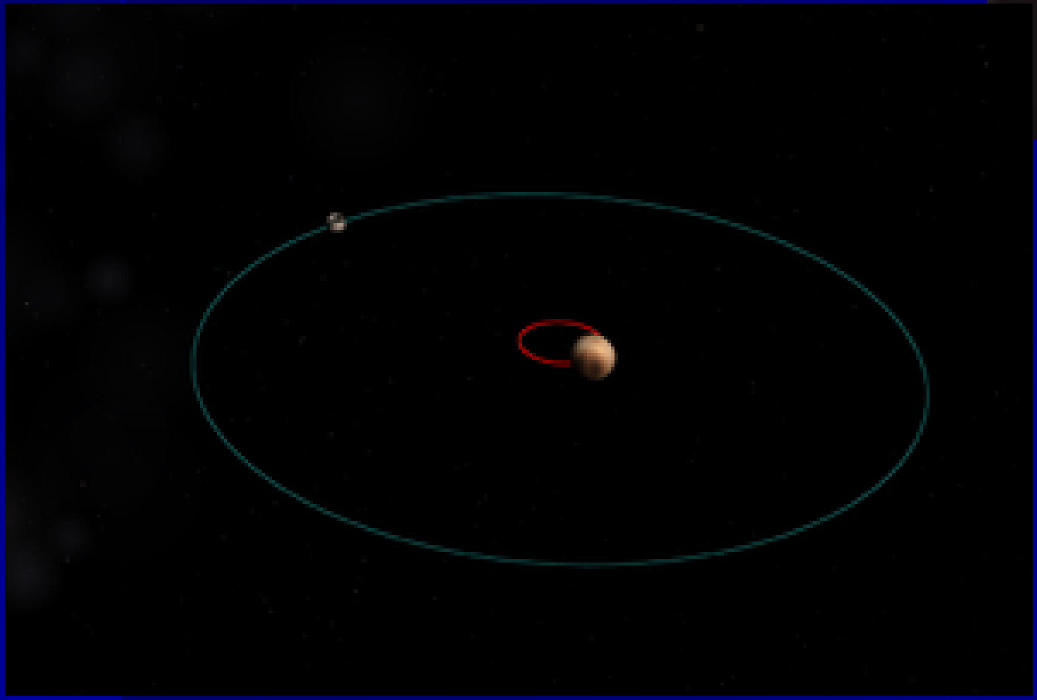
Atmosphere of Charon



Atmosphere of Charon

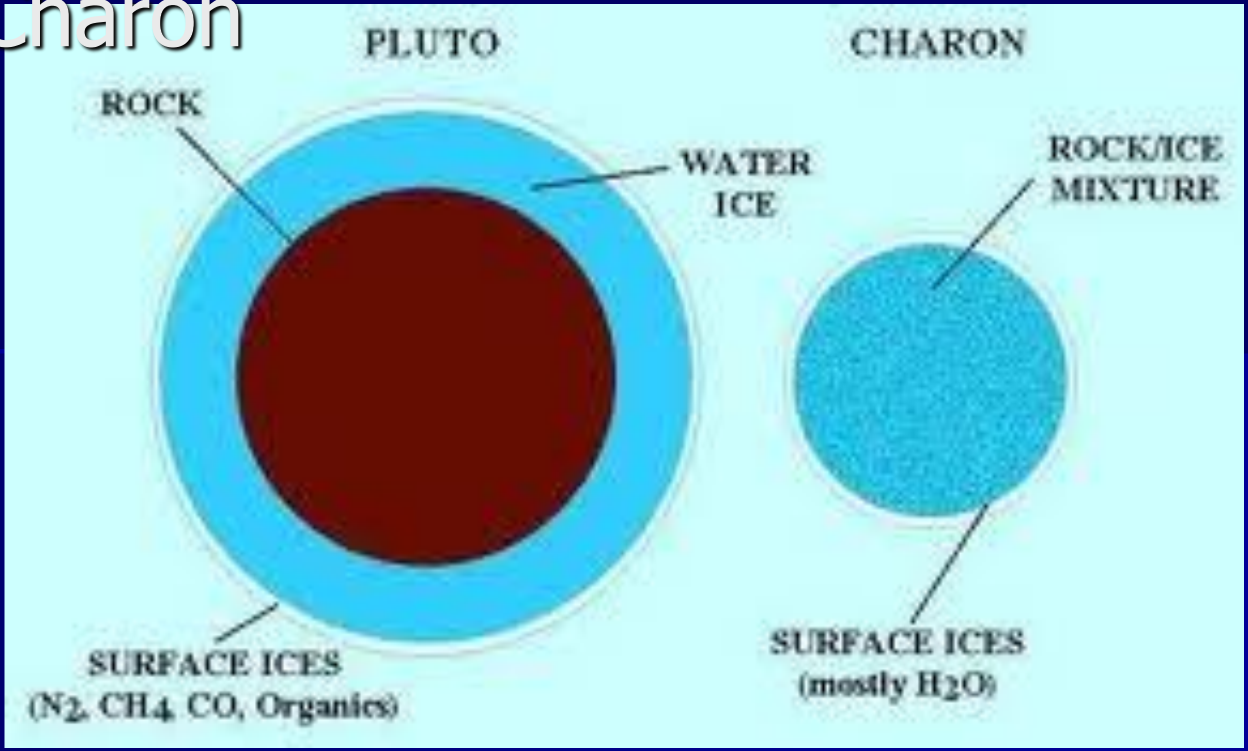
Charon is the largest satellite of the dwarf planet Pluto.(?????)





An oblique view of the Pluto–Charon system showing that Pluto orbits a point outside itself. Pluto's orbit is shown in red and Charon's orbit is shown in green.

Atmosphere of Charon



It was discovered in 1978 at the United States Naval Observatory Flagstaff Station. Following the 2005 discovery of two other natural satellites of Pluto (Nix and Hydra), and in 2011, a fourth, S/2011 P 1, Charon may also be referred to as **(134340) Pluto I**. The New Horizons mission is scheduled to visit Charon and Pluto in July 2015

Atmosphere of Charon

1990 photograph of Pluto and Charon. Taken by the Hubble Telescope.

Charon was discovered by astronomer James Christy on June 22, 1978, when he was examining highly magnified images of Pluto on photographic plates taken a couple of months earlier.

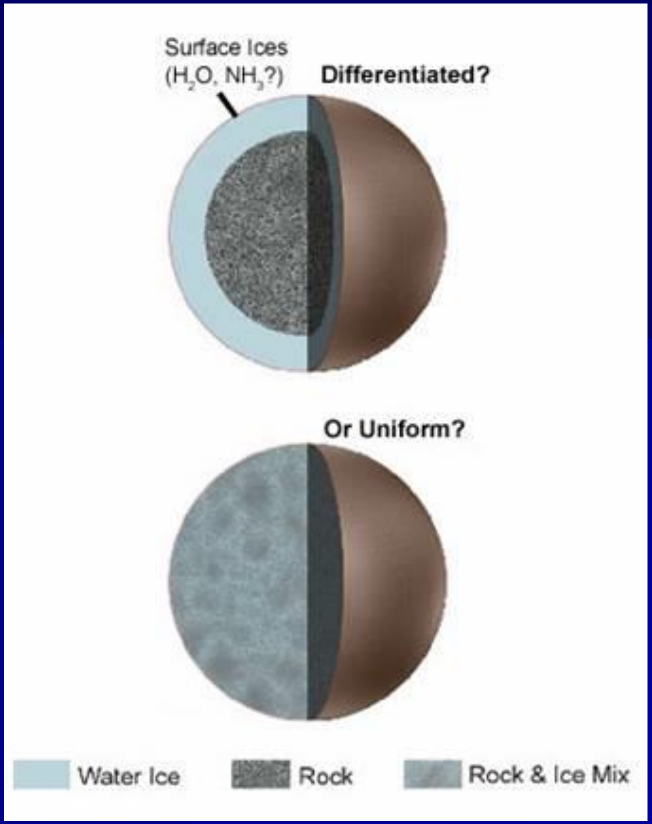
Atmosphere of Charon

1990 photograph of Pluto and Charon. Taken by the Hubble Telescope.

Charon's diameter is about 1,207 kilometres , just over half that of Pluto, with a surface area of 4,580,000 square kilometres . Unlike Pluto, which is covered with nitrogen and methane ices, the Charonian surface appears to be dominated by less volatile water ice, and also appears to have no atmosphere.

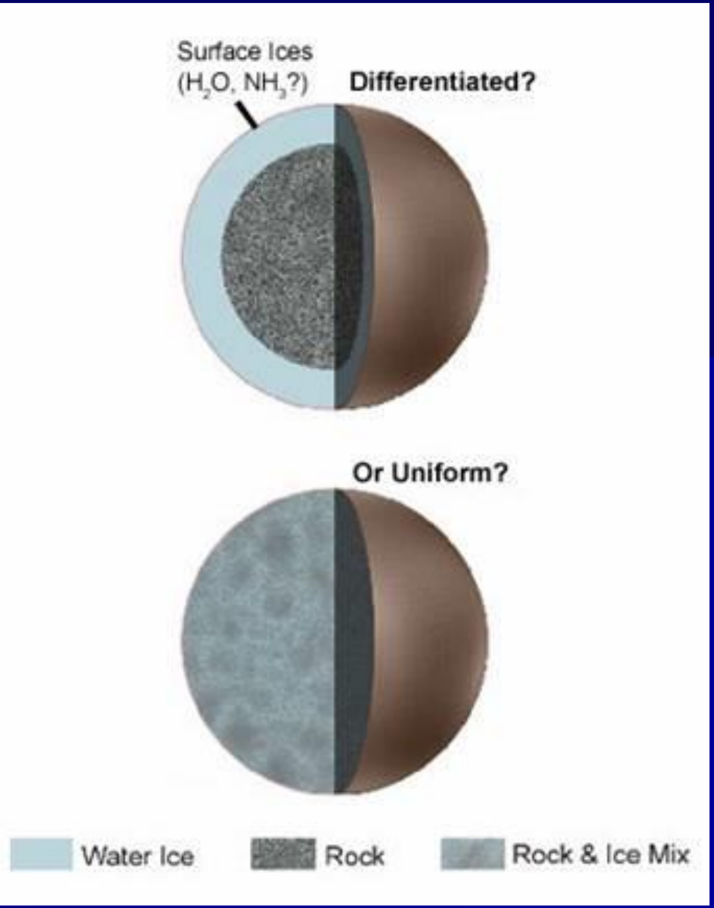
Atmosphere of Charon

Charon's volume and mass allow calculation of its density from which it can be determined that Charon is largely an icy body and contains less rock by proportion than its partner Pluto. This supports the idea that Charon was created by a giant impact into Pluto's icy mantle.



There are two conflicting theories about Charon's internal structure: some scientists believe it to be a differentiated body like Pluto with a rocky core and an icy mantle while others believe Charon to be of uniform composition throughout.

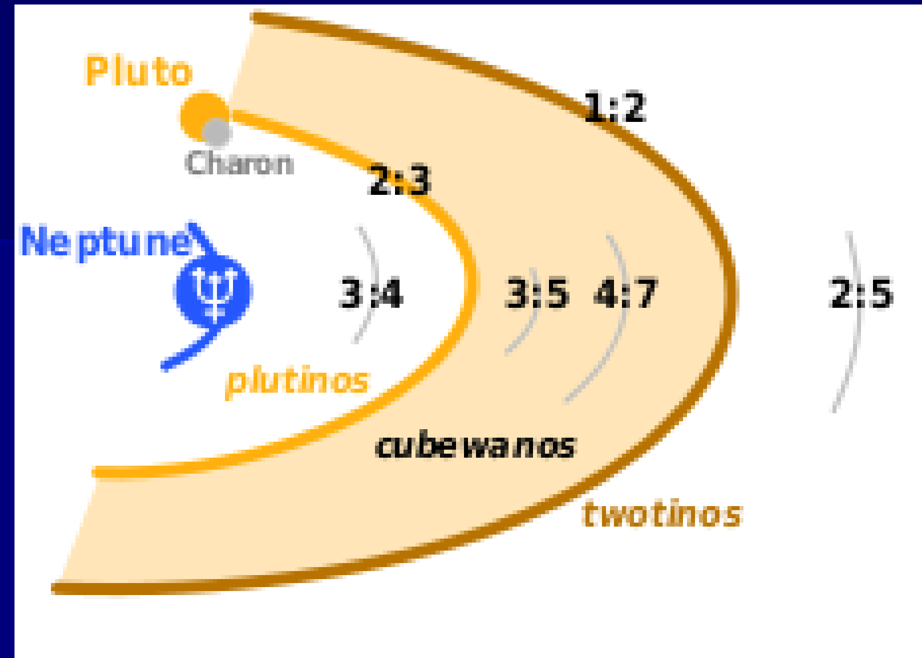
Atmosphere of Charon



Evidence in support of the former position was found in 2007, when observations by the Gemini Observatory of patches of ammonia hydrates and water crystals on the surface of Charon suggested the presence of active cryo-geysers.

Atmosphere of Charon

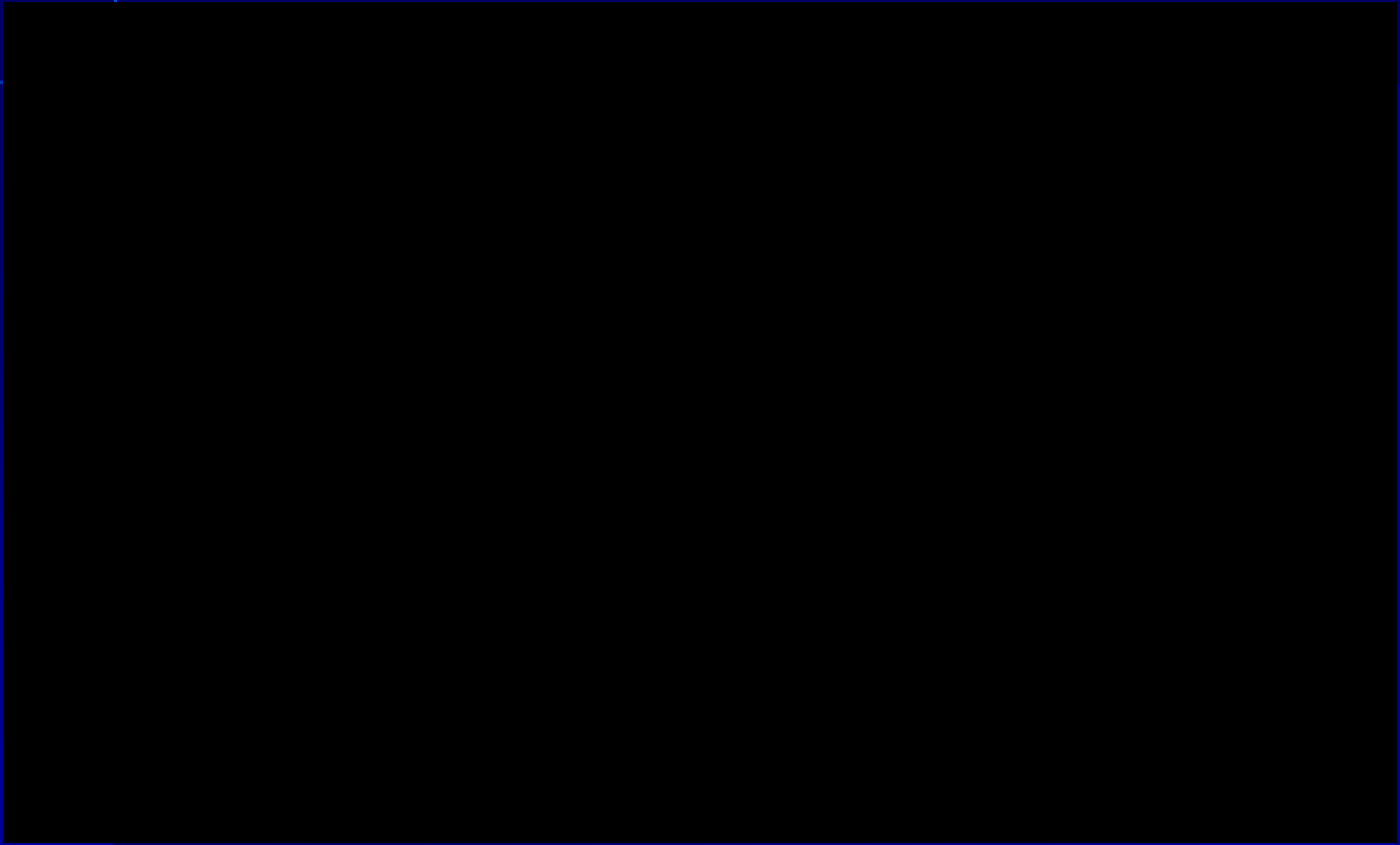
The Plutonian system contains 5 known bodies: Pluto and its four moons.



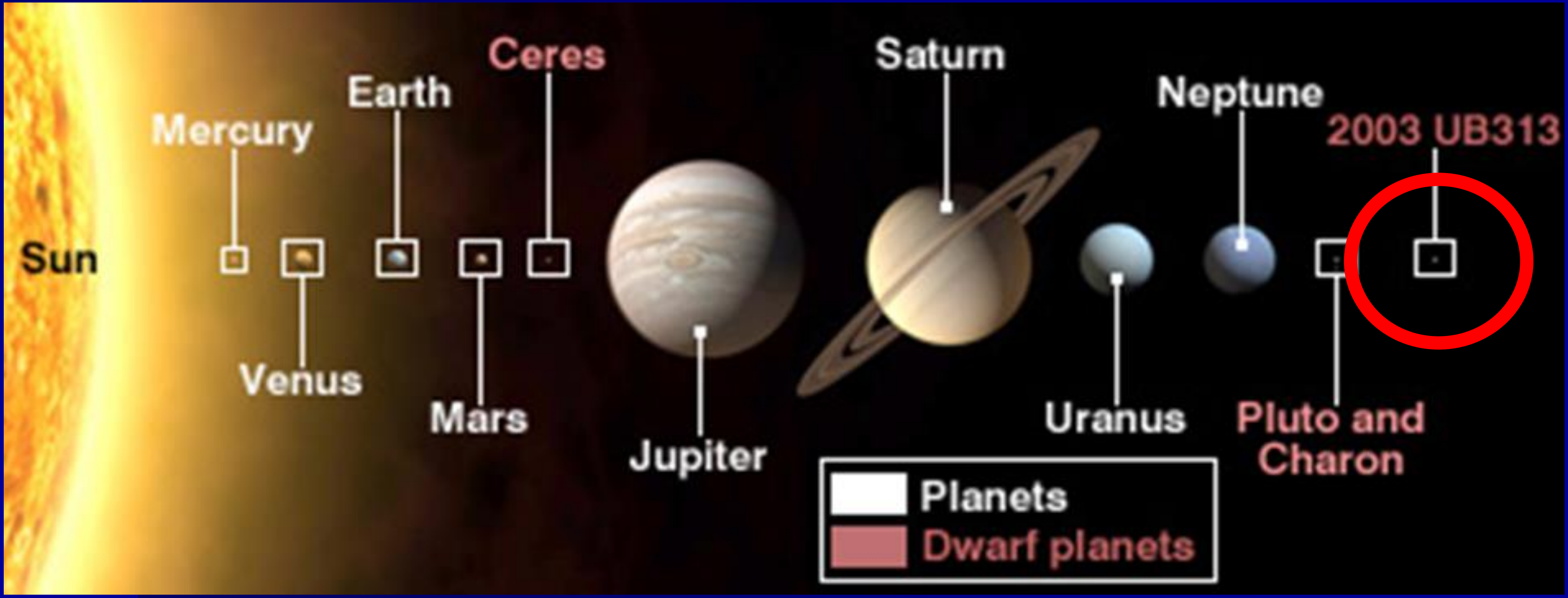
1994 image of Pluto and Charon (right) from ESA/Dornier FOC on the NASA Hubble.

Atmosphere of Charon

Charon Helps Pluto Keep Its Atmosphere



Atmosphere of Eris

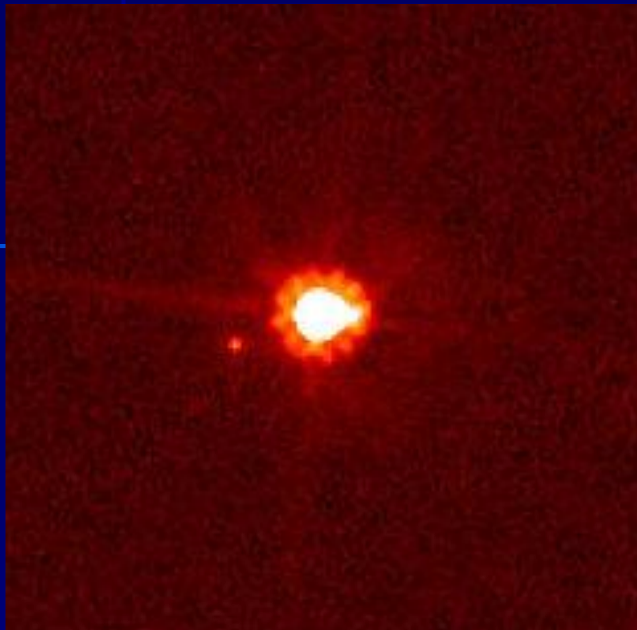


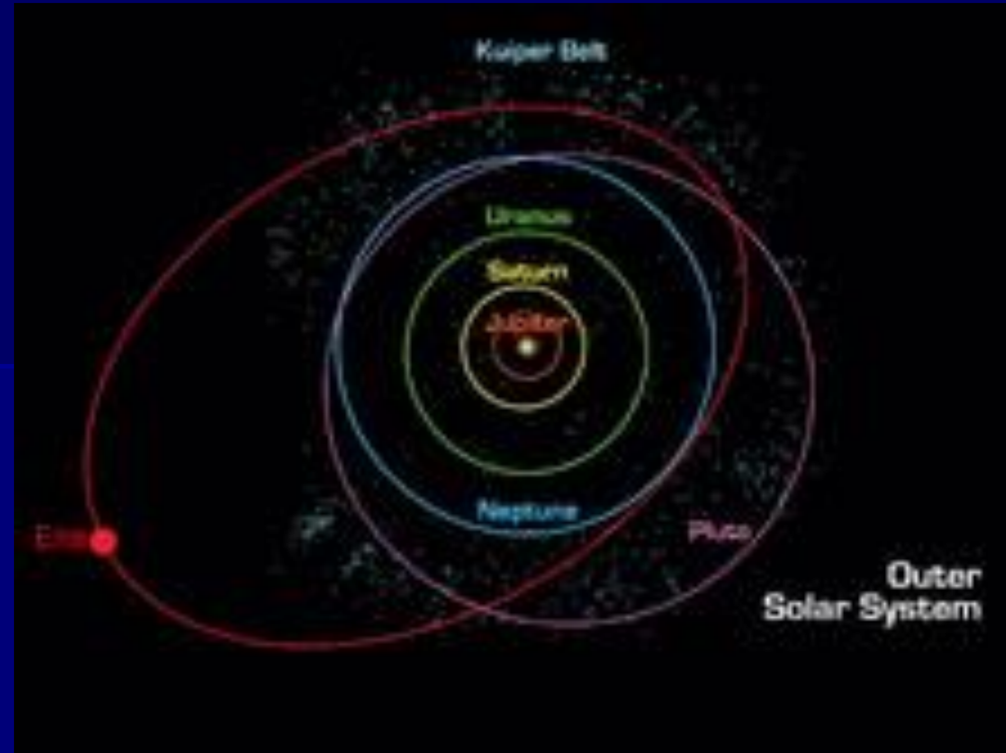
Atmosphere of Eris

Eris, formal designation **136199 Eris**, is the most massive known dwarf planet in the solar system and the ninth most massive body known to orbit the Sun directly.

It is estimated to be approximately 2300–2400 km in diameter, and 27% more massive than Pluto or about 0.27% of the Earth's mass.

Atmosphere of Eris

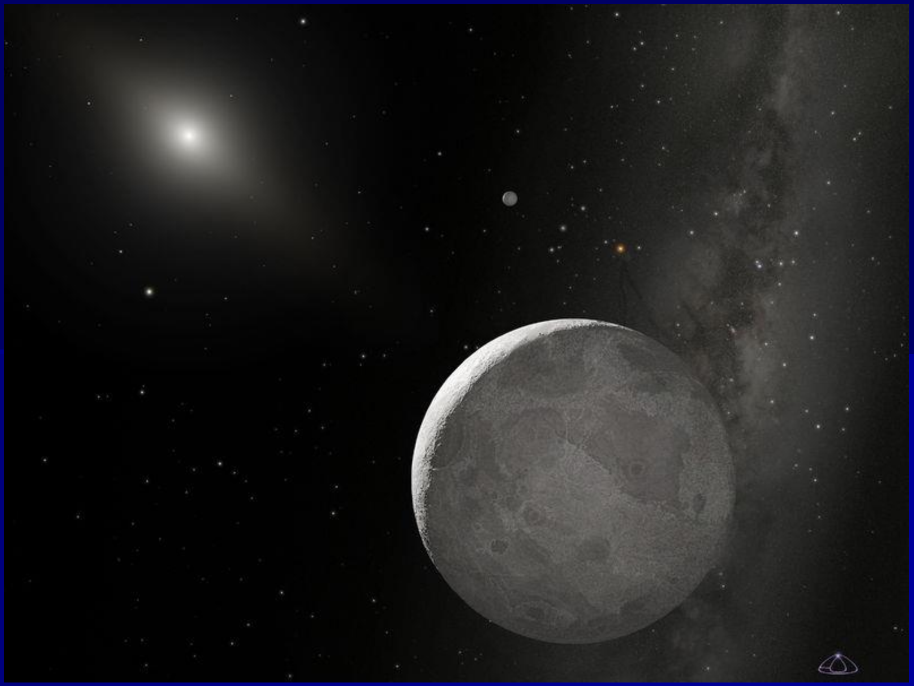




Eris was discovered in January 2005 by a Palomar Observatory - based team led by Mike Brown, and its identity was verified later that year.

Eris has an orbital period of 557 years, and as of 2011 lies at 96.6 AU from the Sun, almost its maximum possible distance (its aphelion (Distance from the Sun) is 97.5 AU).

Atmosphere of Eris



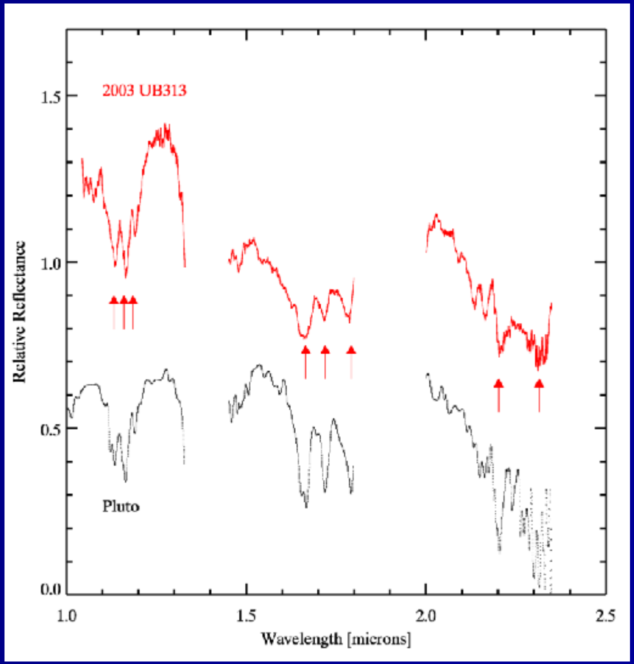
The discovery team followed up their initial identification of Eris with spectroscopic observations made at the 8 m Gemini North Telescope in Hawaii on January 25, 2005.

Infrared light from the object revealed the presence of methane ice, indicating that the surface may be similar to that of Pluto, which at the time was the only TNO known to have surface methane, and of Neptune's moon Triton, which also has methane on its surface.

Atmosphere of Eris

Due to Eris's distant eccentric orbit, Eridian surface temperature is estimated to vary between about 30 and 56 kelvin (−243 and −217 degrees Celsius).

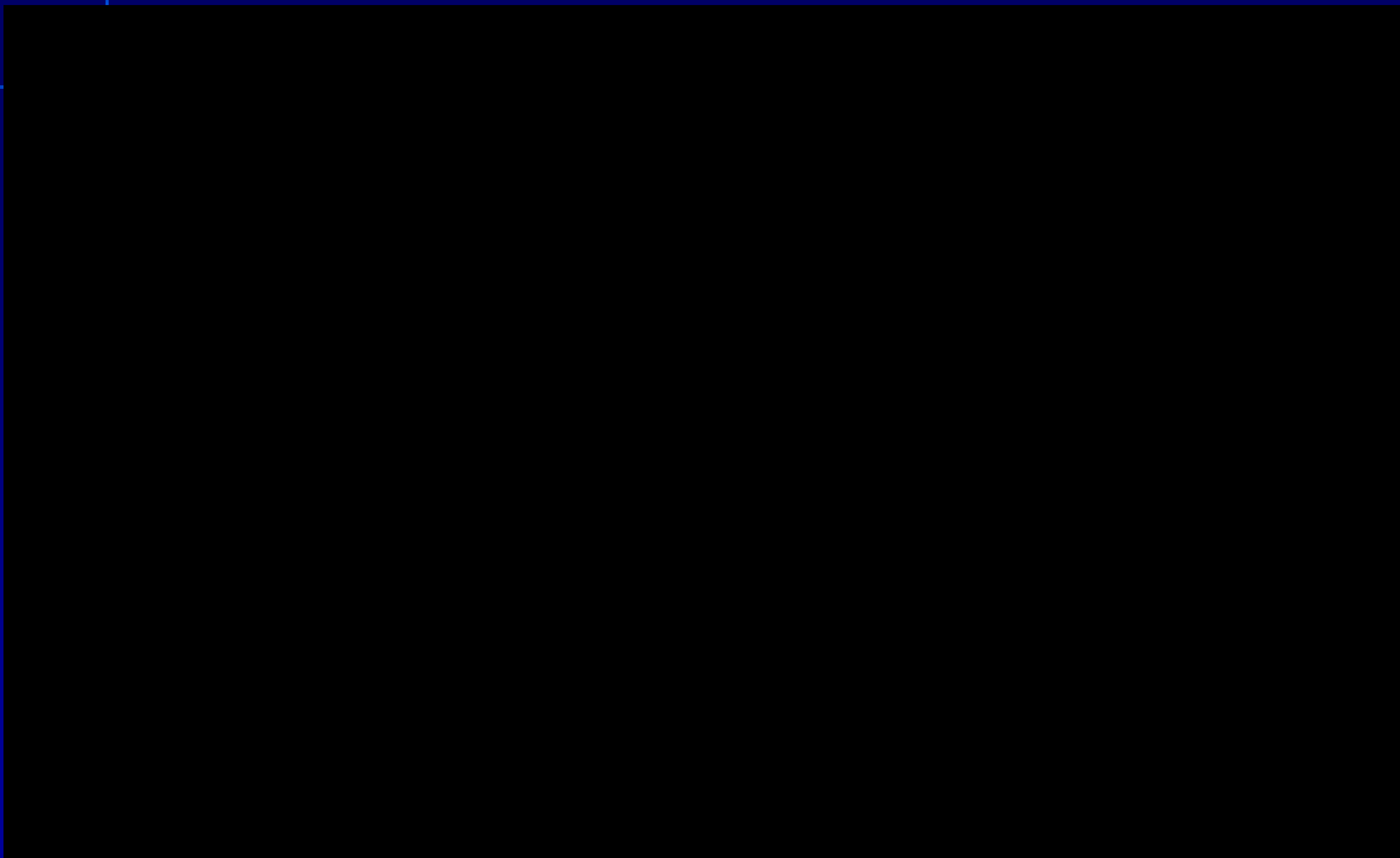
In contrast, Eris is far enough away from the Sun that methane can condense onto its surface even where the albedo is low. The condensation of methane uniformly over the surface reduces any albedo contrasts and would cover up any deposits of red tholins.



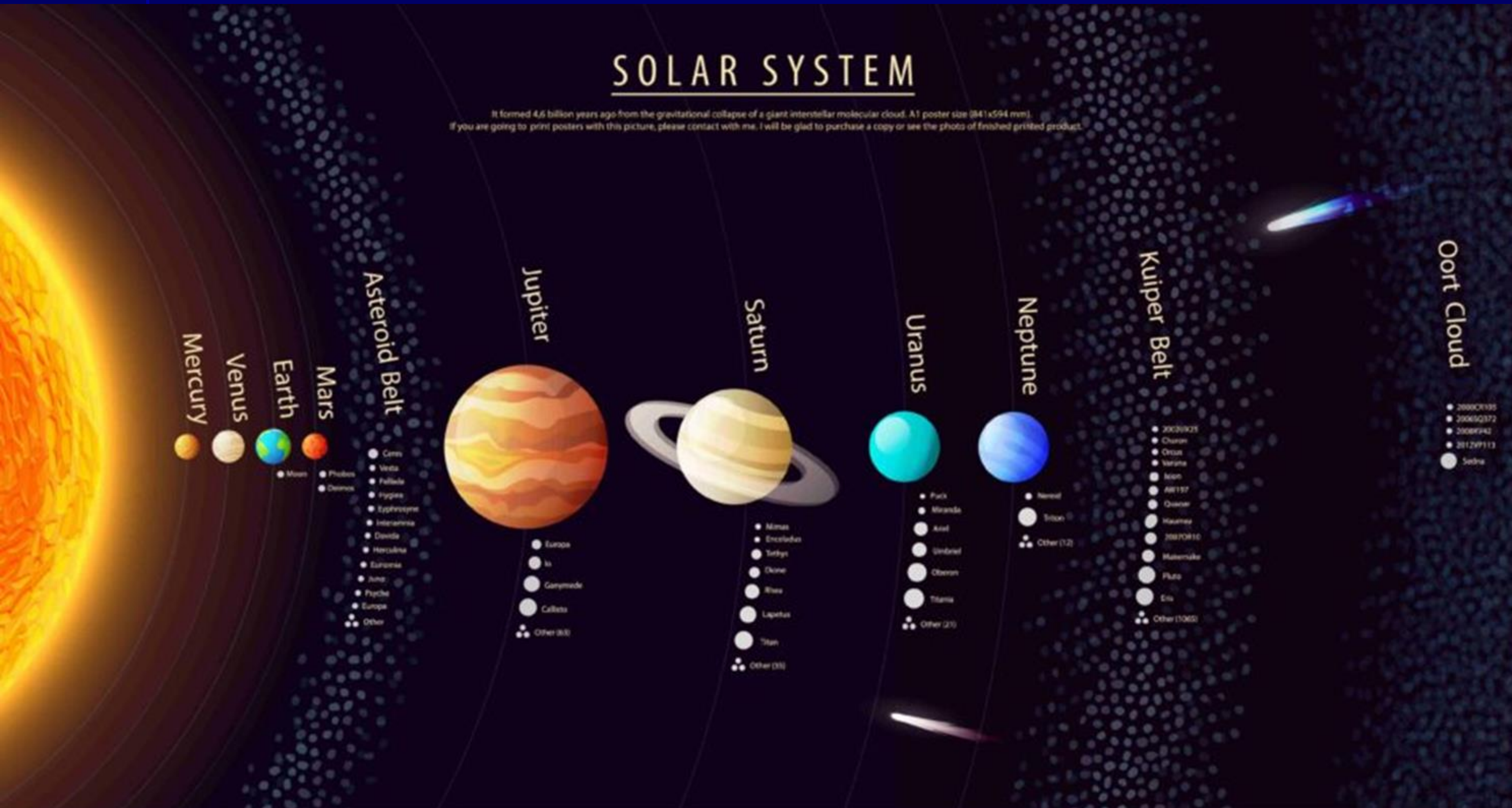
The infrared spectrum of Eris, compared to that of Pluto, shows the marked similarities between the two bodies. Arrows denote methane absorption lines.

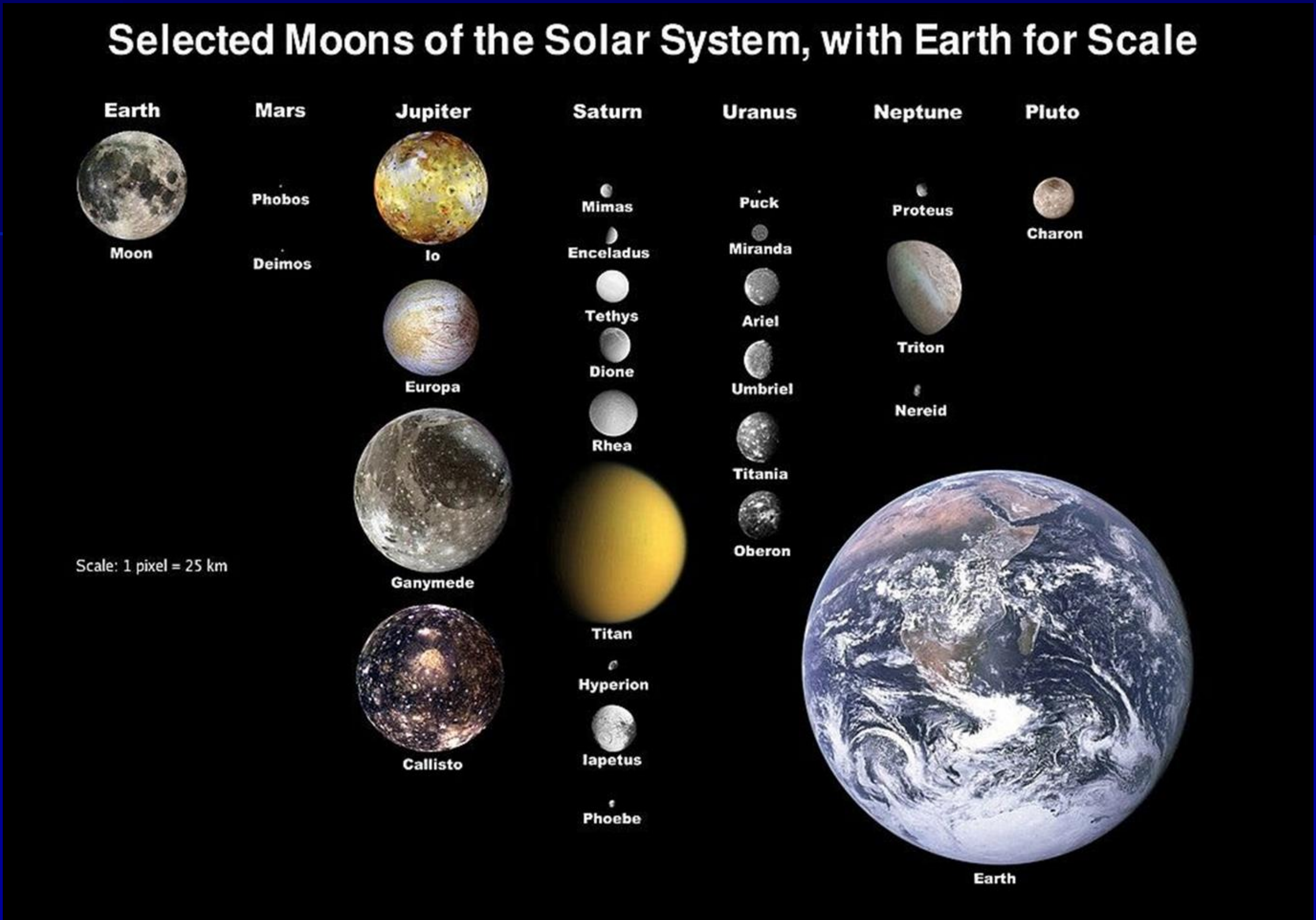
Atmosphere of Eris

Dwarf Planet Eris



Atmospheres of Natural Satellites


SOLAR SYSTEM
It formed 4,6 billion years ago from the gravitational collapse of a giant interstellar molecular cloud. A1 poster size (841x594 mm).
If you are going to print posters with this picture, please contact with me. I will be glad to purchase a copy or see the photo of finished printed product.
Mercury
Venus
Earth
Moon
Mars
Phobos
Deimos
Asteroid Belt
Ceres
Vesta
Pallada
Hygiea
Euphrosyne
Interamnia
Davida
Herculina
Eunomia
Juno
Psyche
Europa
Other
Jupiter
Europa
Io
Ganymede
Callisto
Other (63)
Saturn
Mimas
Enceladus
Tethys
Dione
Rhea
Iapetus
Titan
Other (55)
Uranus
Puck
Miranda
Ariel
Umbriel
Oberon
Titania
Other (21)
Neptune
Nereid
Triton
Other (12)
Kuiper Belt
Charon
Orcus
Haumea
Makemake
Pluto
Eris
Oort Cloud
Sedna


Selected Moons of the Solar System, with Earth for Scale
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
Pluto
Moon
Phobos
Deimos
Io
Europa
Ganymede
Callisto
Mimas
Enceladus
Tethys
Dione
Rhea
Titan
Hyperion
Iapetus
Phoebe
Puck
Miranda
Ariel
Umbriel
Titania
Oberon
Proteus
Triton
Nereid
Charon
Earth
Scale: 1 pixel = 25 km

Jupiter’s

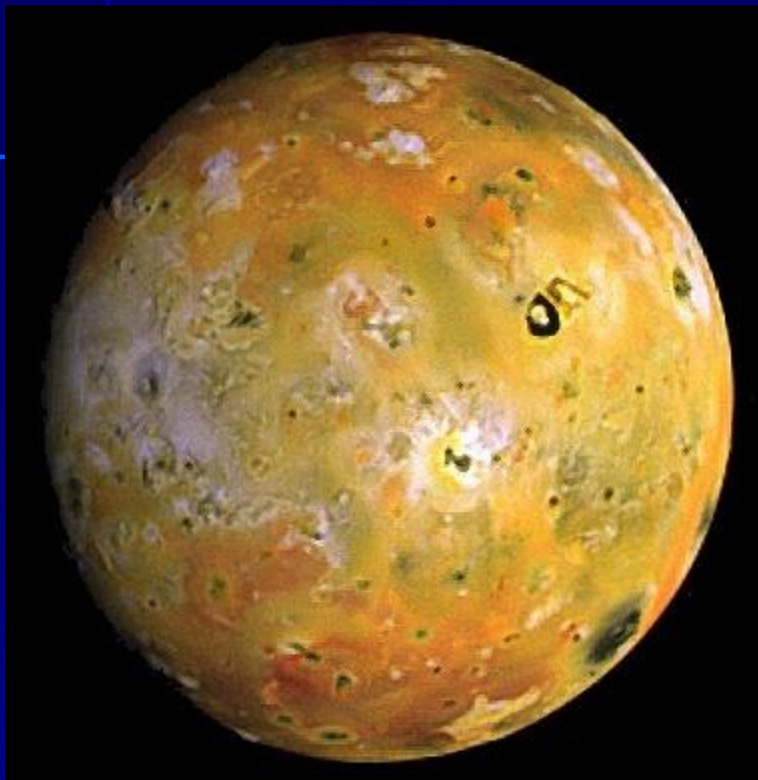
Io

Callisto

Europa

Ganymede

Atmosphere of “Io” - Jupiter



Auroral glows in Io's upper atmosphere. Different colors represent emission from different components of the atmosphere (green comes from emitting sodium, red from emitting oxygen, and blue from emitting volcanic gases like sulfur dioxide). Image taken while Io was in eclipse.

Atmosphere of “Io” - Jupiter

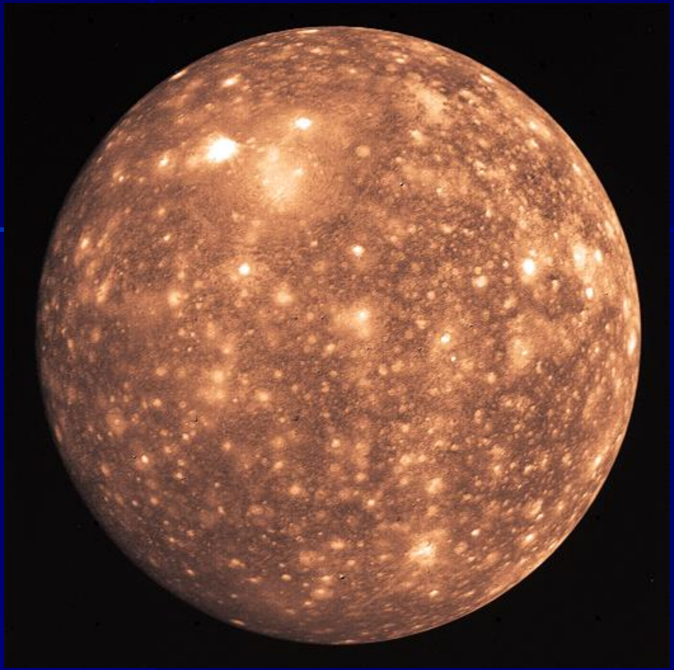
Io has an **extremely thin atmosphere consisting mainly** of sulfur dioxide (SO_2), with minor constituents including sulfur monoxide (SO), sodium chloride (NaCl), and atomic sulfur and oxygen.

The maximum atmospheric pressure on Io ranges from 0.33×10^{-4} to 3×10^{-4} (Pa) or 0.3 to 3 nbar

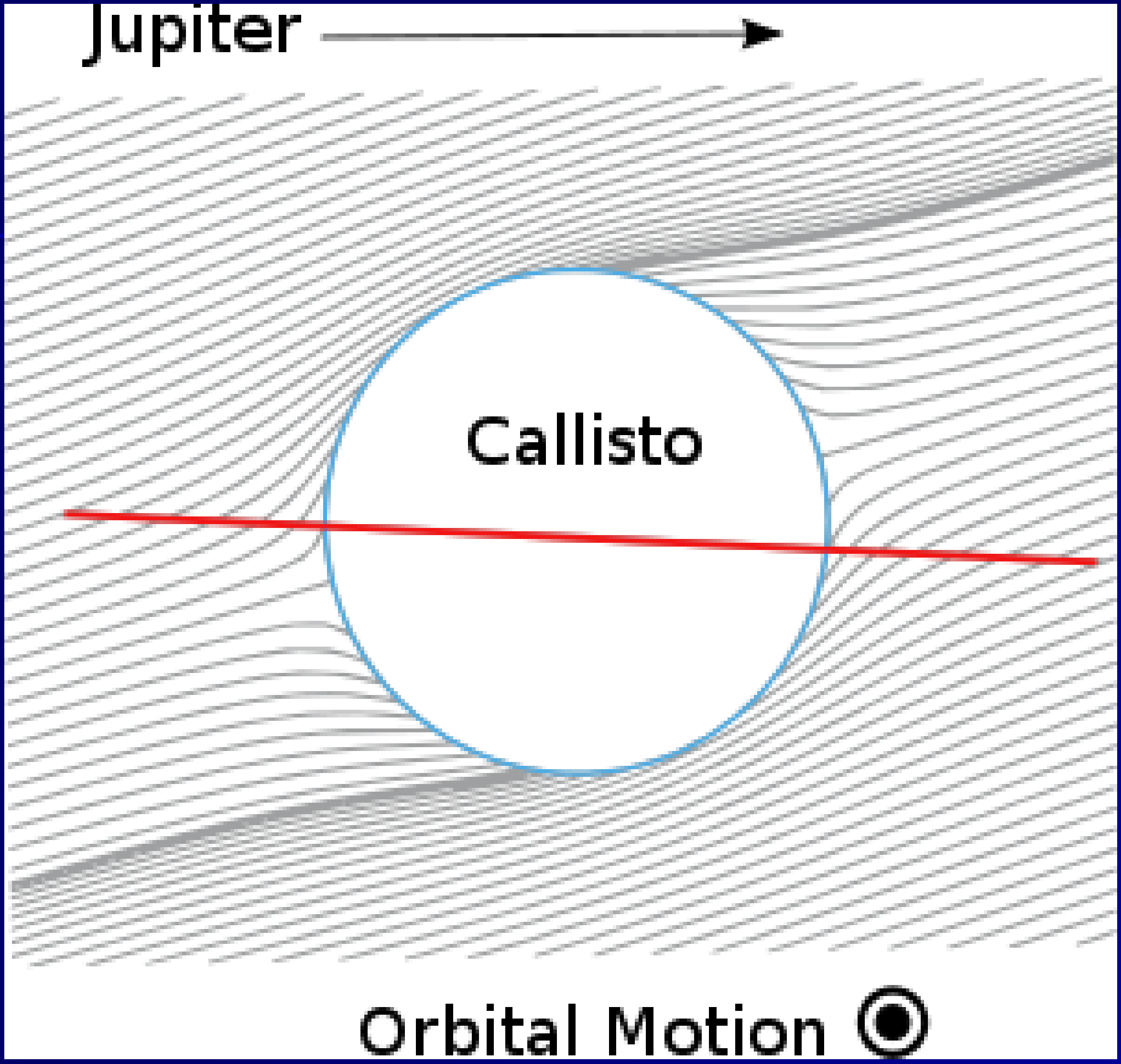
Io's atmospheric temperature ranges from 273 K to 1800 K

Gas in Io's atmosphere is stripped by Jupiter's magnetosphere, escaping to either the neutral cloud that surrounds Io, or the Io plasma torus, a ring of ionized particles that shares Io's orbit but co-rotates with the magnetosphere of Jupiter. Approximately one ton of material is removed from the atmosphere every second through this process

Atmosphere of “Callisto” - Jupiter



Atmosphere of "Callisto" - Jupiter



Induced magnetic field around Callisto

Atmosphere of “Callisto” - Jupiter

Atmosphere and ionosphere

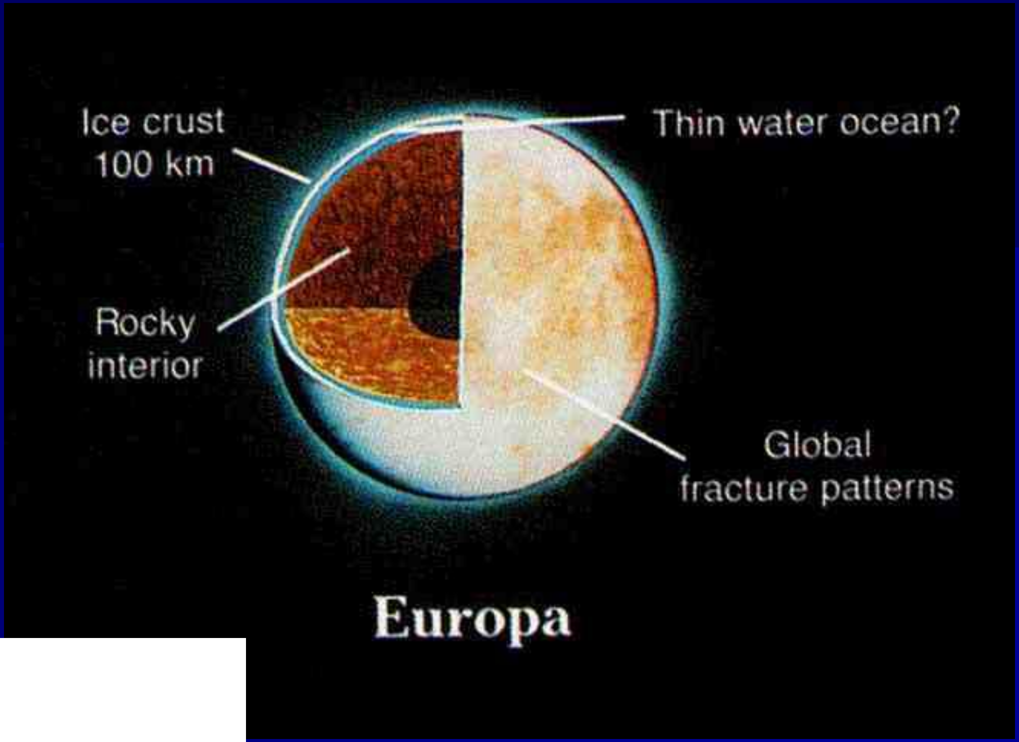
Callisto has a very tenuous atmosphere composed of carbon dioxide.

The surface pressure is estimated to be 7.5×10^{-12} bar (0.75 μPa) and particle density 4×10^{8} cm^{-3}.

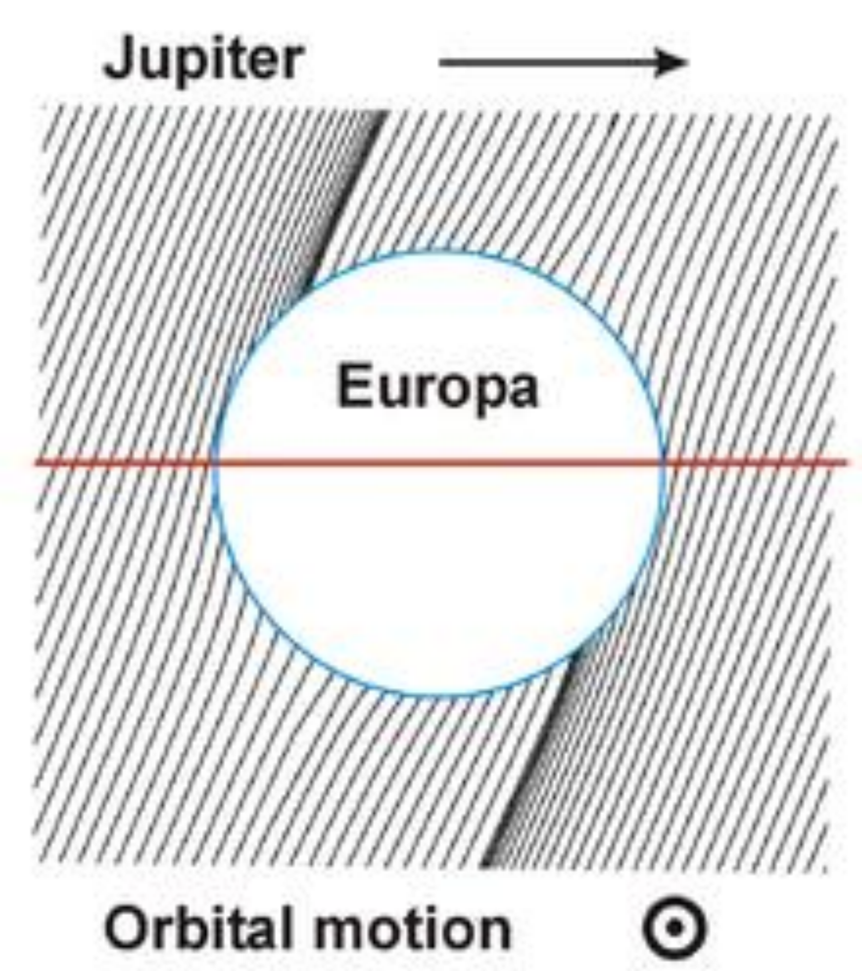
Callisto's ionosphere was detected - *Galileo* flybys; its high electron density of $7 - 17 \times 10^{4}$ cm^{-3}

HST (Hubble Space Telescope) was able to detect condensed oxygen trapped on the surface of Callisto.

Atmosphere of "Europa" - Jupiter



Atmosphere of “Europa” - Jupiter



Magnetic field around Europa. The red line shows a trajectory of the *Galileo* spacecraft during a typical flyby

Atmosphere of “Europa” - Jupiter

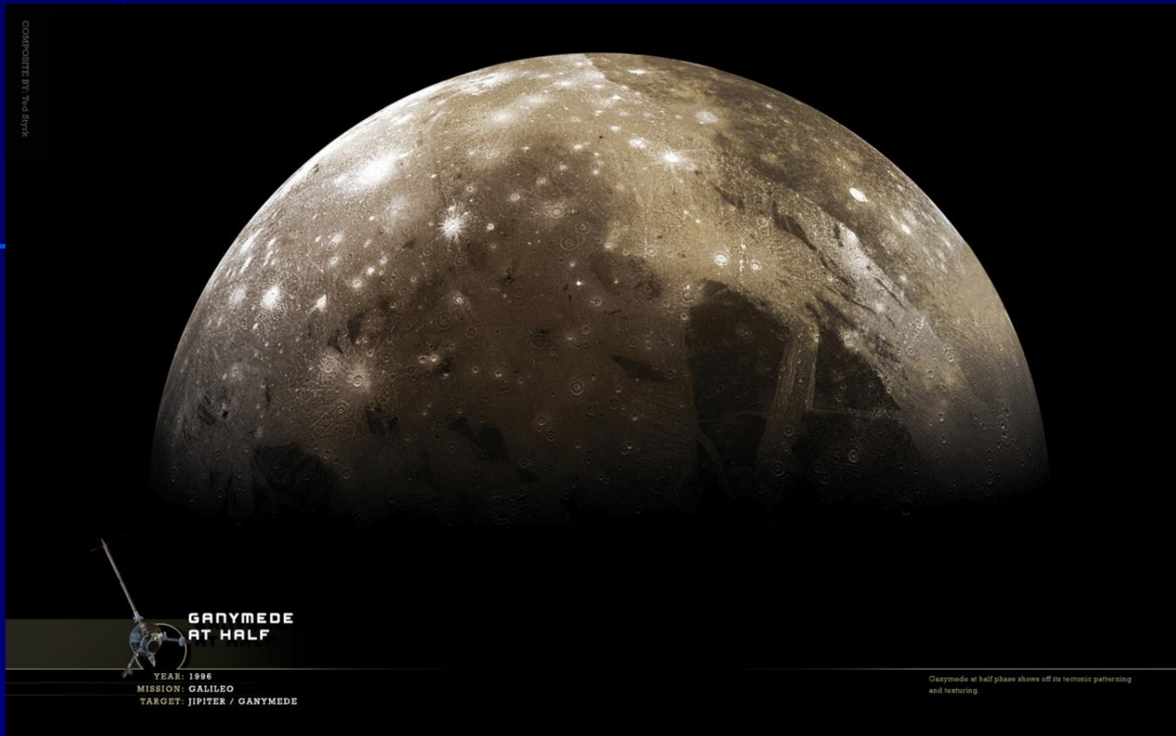
Europa has a tenuous atmosphere composed mostly of molecular oxygen (O_2).

The surface pressure of Europa's atmosphere is 0.1 μPa, or 10^{-7} times that of the Earth.

In 1997, the Galileo spacecraft **confirmed the presence of a tenuous ionosphere around Europa** created by solar radiation and energetic particles from Jupiter's magnetosphere, providing evidence of an atmosphere.

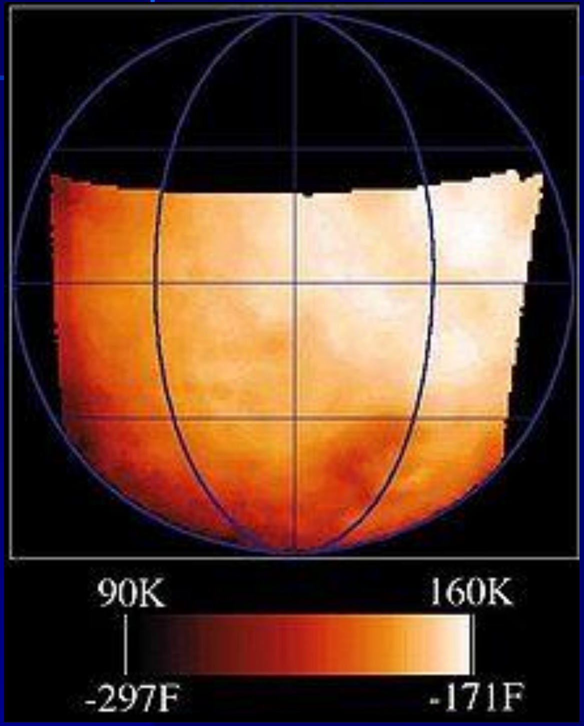
Unlike the oxygen in Earth’s atmosphere, Europa's is not of biological origin.

Atmosphere of “Ganymede” - Jupiter



Atmosphere of “Ganymede” - Jupiter

Atmosphere and ionosphere



False colour temperature map of Ganymede

In 1972, a team of Indian, British and American astronomers had detected a thin atmosphere

They estimated that the surface pressure was around 0.1 Pa.

The upper limit on the surface particle number density was found to be $1.5 \times 10^9\ cm^{-3}$, which corresponds to a surface pressure of less than 2.5 μPa.

Atmosphere of "Ganymede" - Jupiter

Atmosphere and ionosphere…

The existence of a neutral atmosphere implies that an ionosphere should exist, because oxygen molecules are ionized by the impacts of the energetic electrons coming from the magnetosphere and by solar EUV radiation.

The electron density near the surface is estimated by different sources to lie in the range 400 – 2,500 cm^{-3}. As of 2008, the parameters of the ionosphere of Ganymede are not well constrained.

Atmosphere of “Ganymede” - Jupiter

Atmosphere and ionosphere…

The detection of ozone (O_3) bands was announced in 1996.

Laboratory work has found that O_2 would not cluster or bubble but dissolve in ice at Ganymede's relatively warm surface temperature of 100 K.

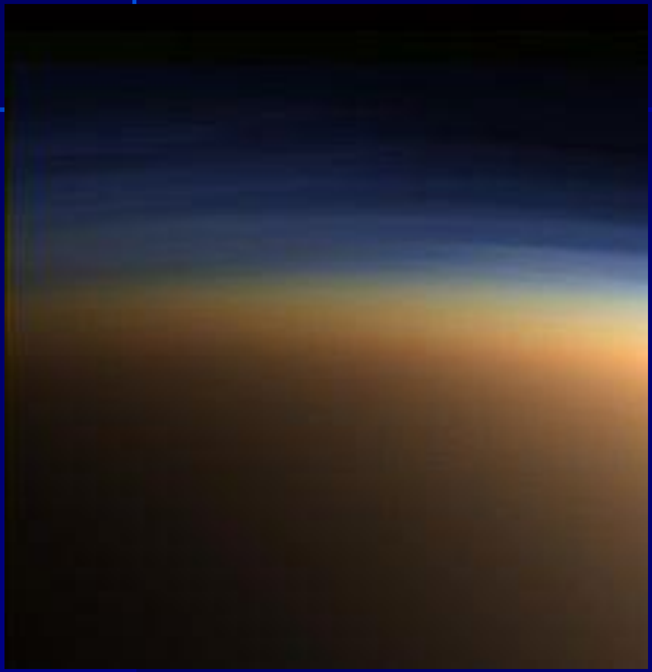
Saturn’s

Titan

Enceladus

Atmosphere of "**Titan**" - Saturn

Atmosphere of "**Titan**" - Saturn



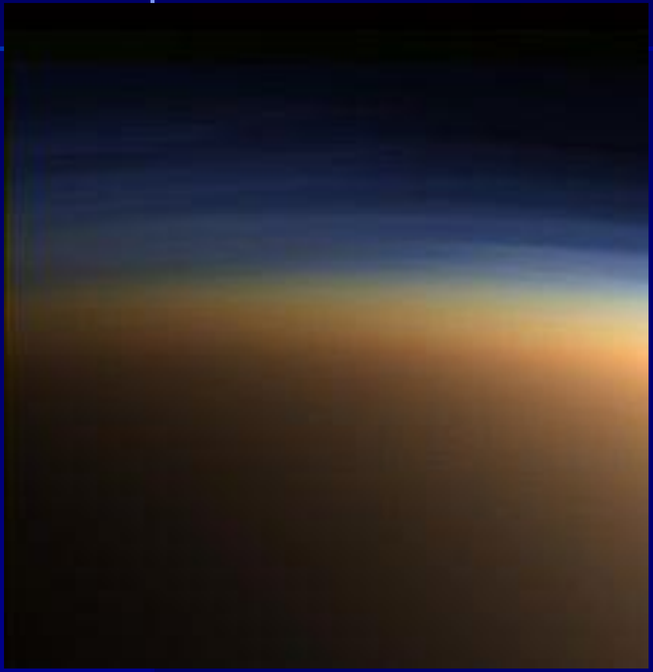
True-color image of layers of haze in Titan's atmosphere.

The atmosphere of Titan is known as the only fully developed atmosphere that exists on a natural satellite in our solar system.

History

In 1981, Voyager 1 made the first detailed observations of Titan's atmosphere, revealing that its surface pressure was in fact thicker than Earth's, at 1.5 bars.

Atmosphere of "**Titan**" - Saturn

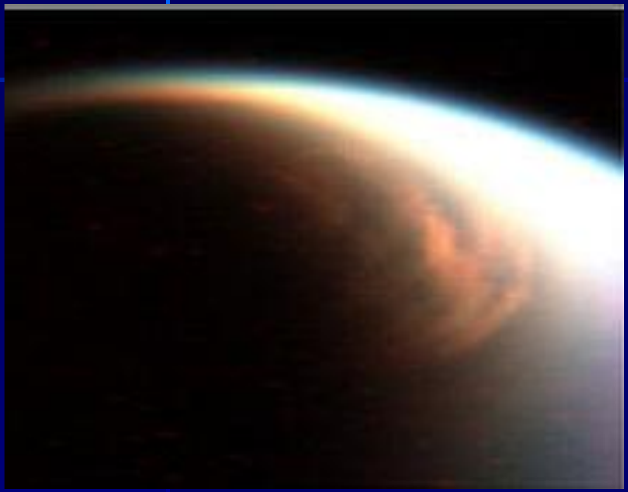


True-color image of layers of haze in Titan's atmosphere.

Extent

Observations from the Voyager space probes have shown that the Titanian atmosphere is denser than Earth's, with a surface pressure about 1.45 times that of Earth's. Titan's atmosphere is about 1.19 times as massive as Earth's overall

Atmosphere of “**Titan**” - Saturn

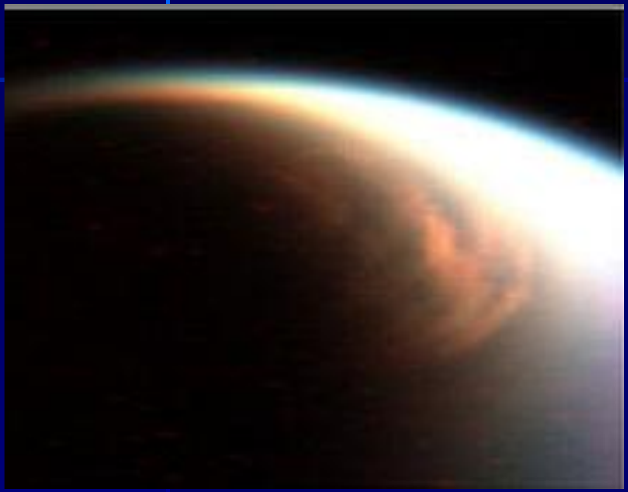


A cloud imaged in false color over Titan's north pole.

Composition

The atmospheric composition in the stratosphere is 98.4% nitrogen the only dense, nitrogen-rich atmosphere in the Solar System aside from the Earth's - with the remaining 1.6% composed of mostly of methane (1.4%) and hydrogen (0.1–0.2%).

Atmosphere of "**Titan**" - Saturn



A cloud imaged in false color over Titan's north pole.

There are trace amounts of other hydrocarbons, such ethane, diacetylene, methylacetylene, acetylene and propane, and of other gases, such as cyanoacetylene, hydrogen cyanide, carbon dioxide, carbon monooxide, cyanogen, argon and helium.

Atmosphere of “**Titan**” - Saturn

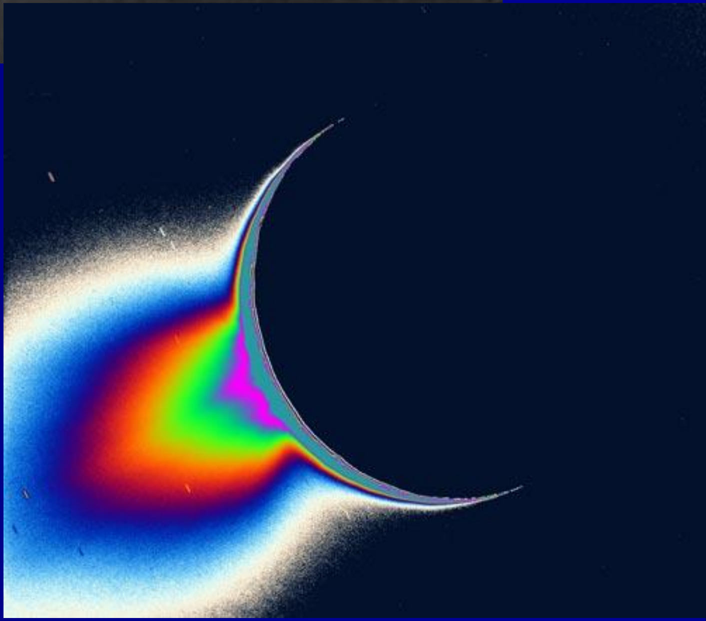
Layers of atmosphere, image from the Cassini - Huygens spacecraft

Evolution

Titan's surface temperature is also quite low, about 90 K.

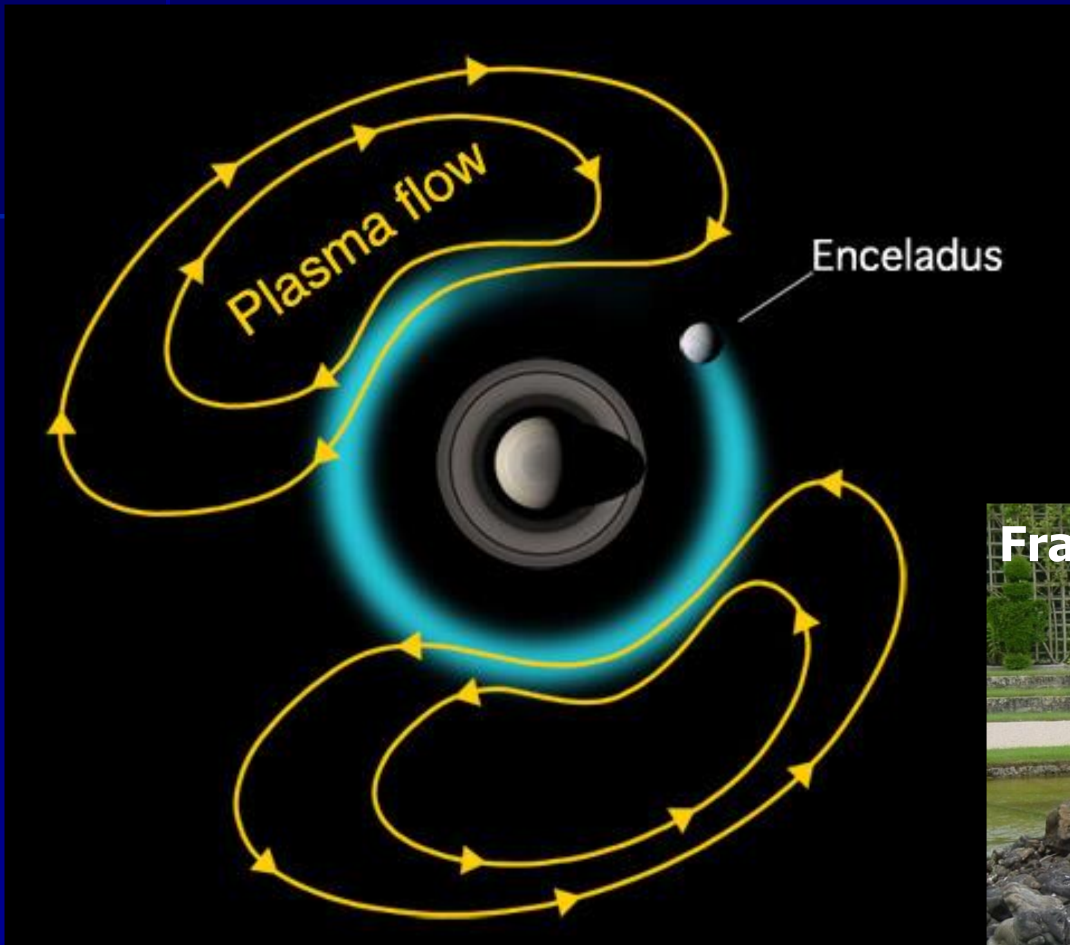
In fact, current interpretations suggest that only about 50% of Titan's mass is silicates, with the rest consisting primarily of various H_2O (water) ices and NH_3-H_2O (ammonia hydrates).

Atmosphere of “**Enceladus**” - Saturn



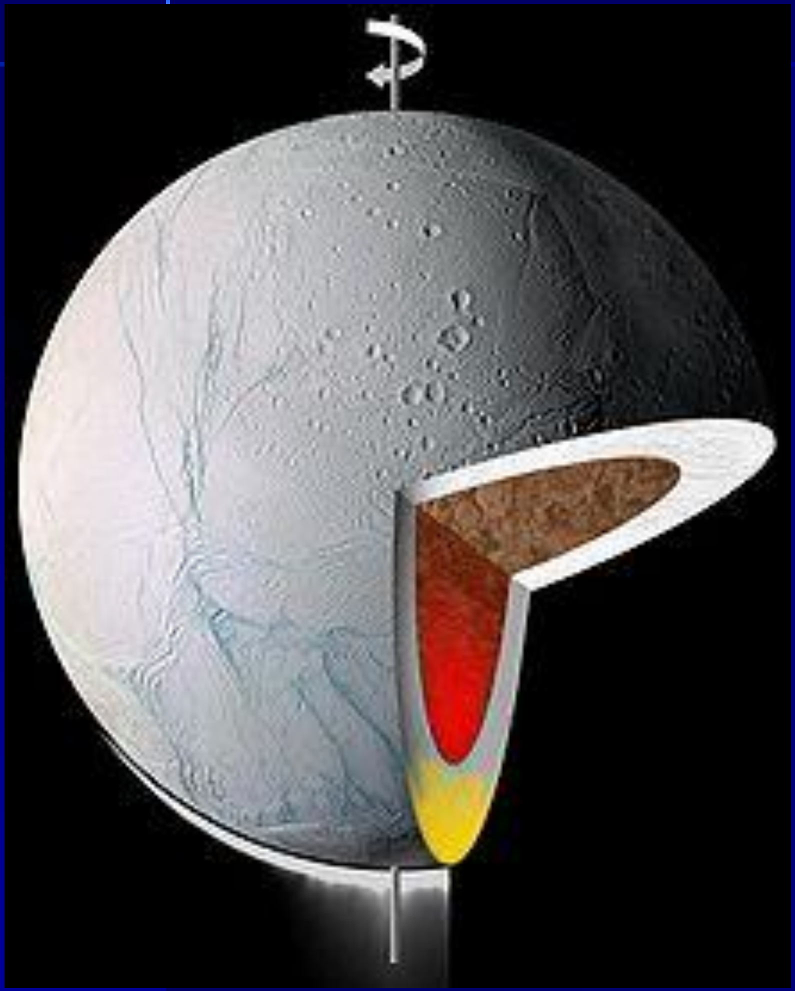
Plumes above the limb of Enceladus feeding the E ring. These appear to emanate from the "tiger stripes" near the south pole. (View from Cassini spacecraft)

Atmosphere of “**Enceladus**” - Saturn



Atmosphere of "**Enceladus**" - Saturn

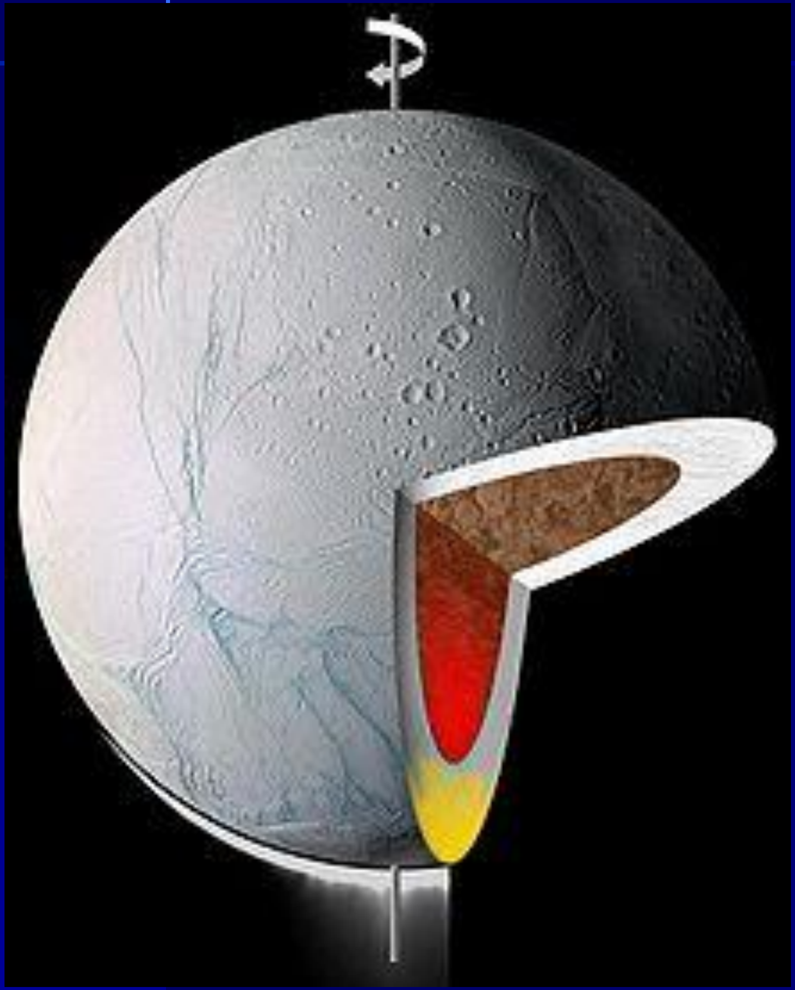
Internal structure



Model of the interior of Enceladus based on recent *Cassini* findings. The inner, silicate core is represented in brown, while the outer, water-ice-rich mantle is represented in white. The yellow and red colours in the mantle and core respectively represent a proposed diaper under the south pole.

Atmosphere of “**Enceladus**” - Saturn

Internal structure



Mass estimates from the Voyager program missions suggested that **Enceladus was composed almost entirely of water ice.**

Atmosphere of “**Enceladus**” - Saturn

Possible water ocean

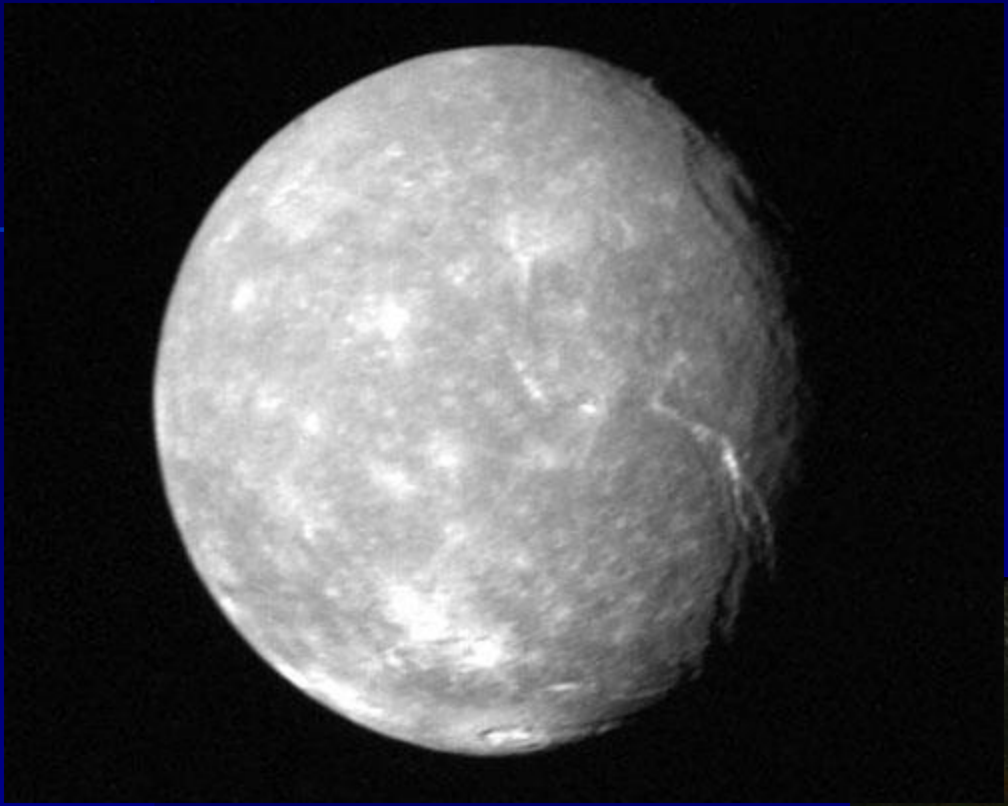
In late 2008, scientists observed water vapor spewing from Enceladus's surface. This could indicate the presence of liquid water, which might also make it possible for Enceladus to support life.

Particles of ice analysed by Cassini revealed that the ice was of salt water which could, it is surmised, only occur in a large liquid body of water; as such Enceladus is a candidate for the harbouring of extra-terrestrial life.

Uranus's

Titania

Atmosphere of “**Titania**” - Uranus



Atmosphere of "**Titania**" - Uranus

The presence of carbon dioxide on the surface suggests that Titania may have a tenuous seasonal atmosphere of CO_2, much like that of the Jovian moon Callisto. Other gases like nitrogen or methane are unlikely to be present, because the moon's weak gravity could not prevent them escaping into the space. **At the maximum temperature attainable during Titania's summer solstice (89 K), the vapour pressure of carbon dioxide is about 3 nbar.**

Atmosphere of “**Titania**” - Uranus

During the summer, when the polar temperatures reach as high as 85–90 K, carbon dioxide sublimates and migrates to the opposite pole and to the equatorial regions, giving rise to a type of carbon cycle.

Neptune's

Triton

Atmosphere of “**Triton**” - Neptune

Atmosphere of "**Triton**" - Neptune

The atmosphere of Triton extends 800 kilometres above Triton's surface. The atmosphere mainly is composed of nitrogen, similar to Titan's atmosphere and Earth's atmosphere. The surface pressure is only 14 microbars, which is 1/70,000th of the surface pressure on Earth. **Originally, it was thought Triton had a thick atmosphere.**

Atmosphere of “**Triton**” - Neptune

Composition

Nitrogen is the main gas in Triton's atmosphere. The two other known components are methane and carbon monoxide, which abundances are a few hundredths of a per cent of that of the nitrogen. Carbon monoxide, which was discovered only in 2010 by the ground based observations, is slightly more abundant than methane.

Other possible components of the Triton's atmosphere include argon and neon.

Atmosphere of “**Triton**” - Neptune

Structure

Triton's atmosphere is well structured and global. The atmosphere extends up to 800 kilometres above the surface, where the exobase is located, and had a surface pressure of about 14 microbars as of 1989. This is only 1/70,000th of the surface pressure on Earth.

The surface temperature was at least 35.6 K (−237.6 °C) because, transition between hexagonal and cubic nitrogen ice occurs at that temperature.

Atmosphere of “**Triton**” - Neptune

Structure

Convection near Triton's surface heated by the Sun creates a troposphere rising to an altitude of about 8 km. In it temperature decreases with height reaching a minimum of about 36 K at the tropopause.

Higher regions include the thermosphere (200–850 km) and exosphere (above 850 km). The thermosphere has a constant temperature of about 95 K.


Thank You !