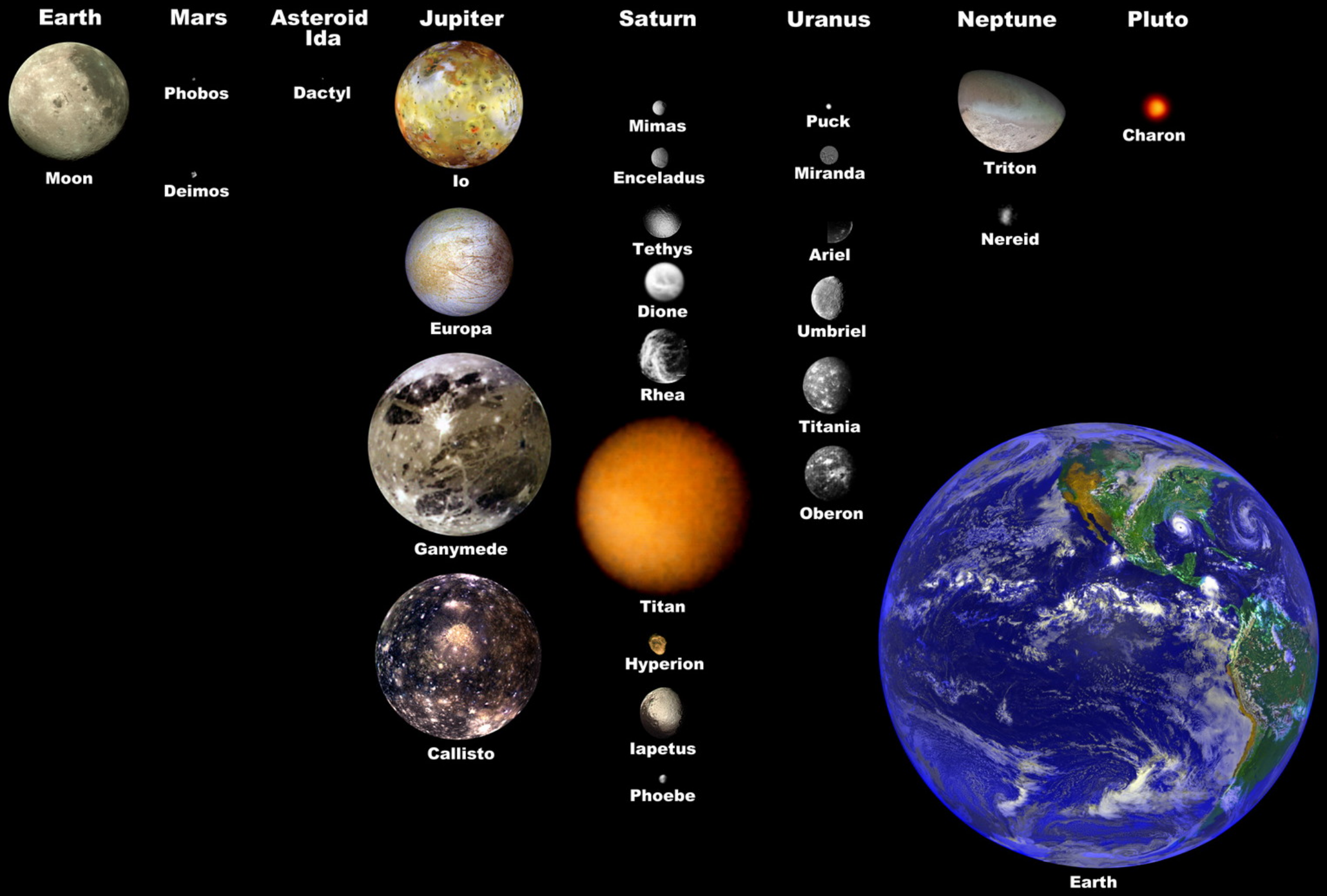
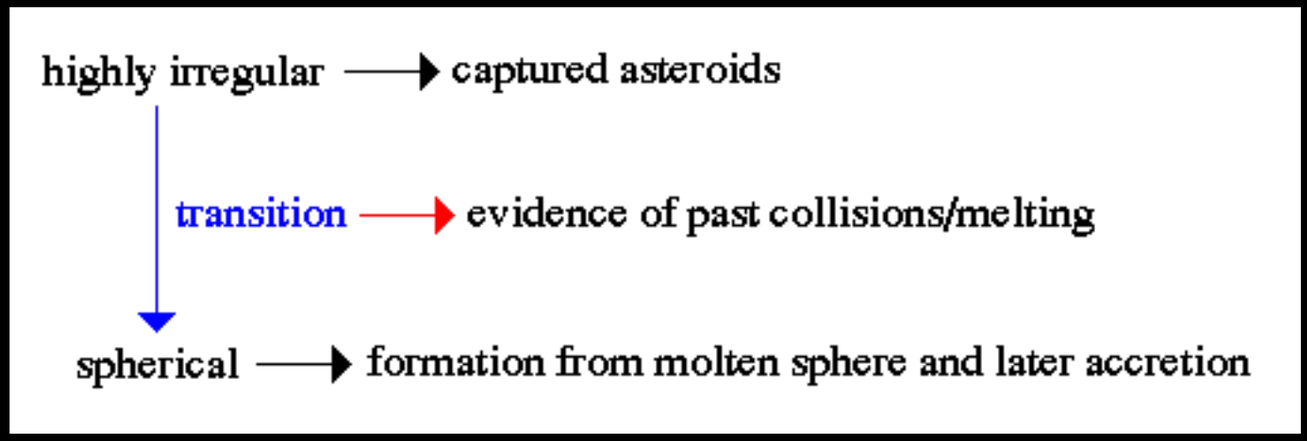
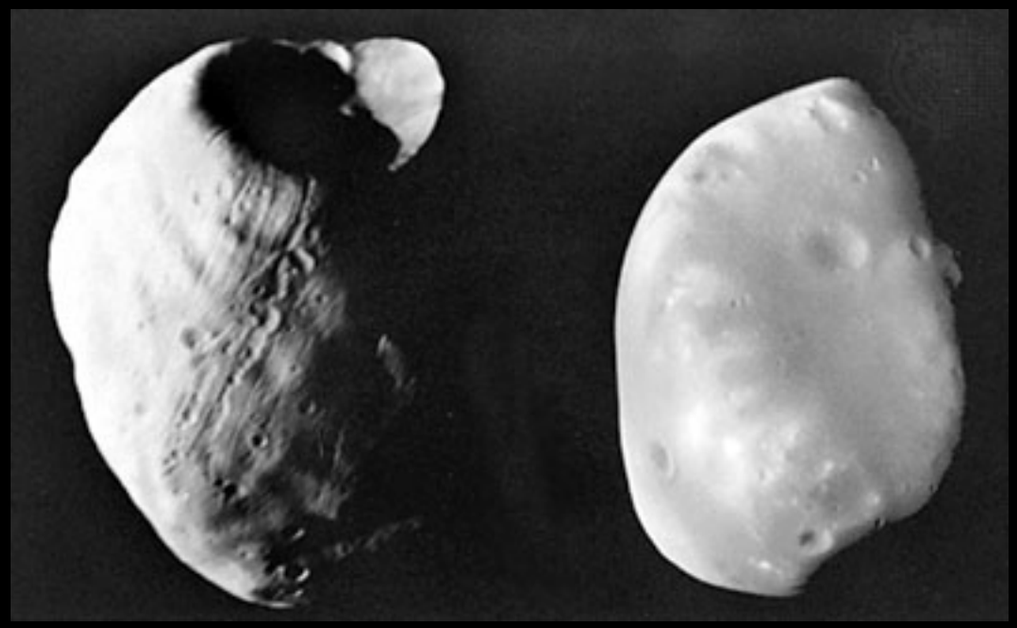


Moons are `fossils" into a planet's past.



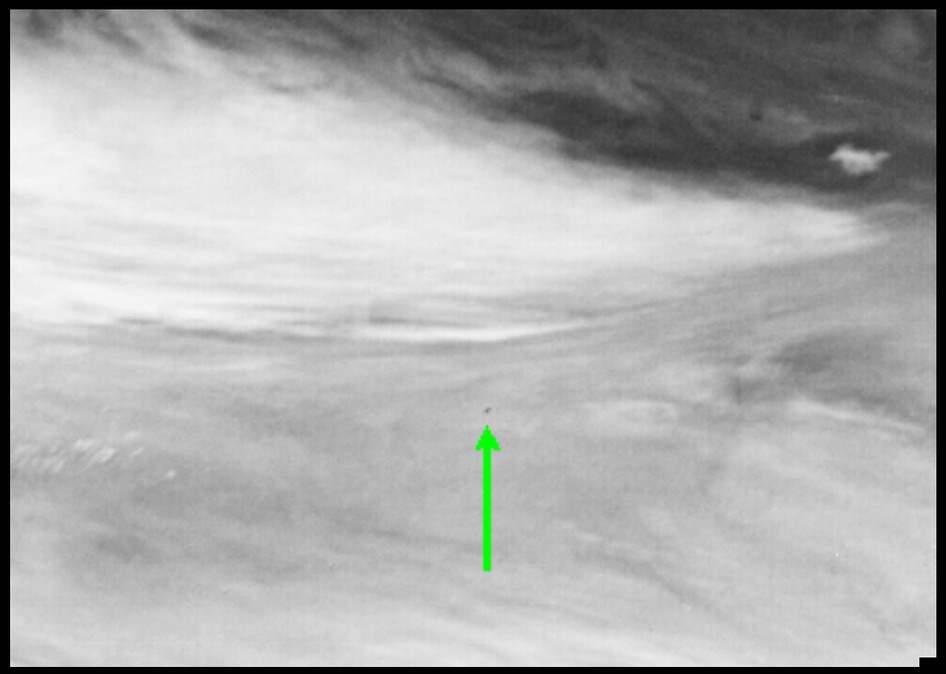
The "traditional" moon count most people are familiar with stands at 268: One moon for Earth; two for Mars; 95 at Jupiter; 124 at Saturn; 27 at Uranus; 14 at Neptune; and five for dwarf planet Pluto. According to NASA/JPL's Solar System Dynamics team, astronomers have documented more than 460 natural satellites orbiting smaller objects, such as asteroids, dwarf planets, or Kuiper Belt Objects (KBOs) beyond the orbit of Neptune.

While every moon may reflect its unique history and environment, they all can help us understand the formation and evolution of the Solar System. The chemical composition and structure of moons are clues to their origin, and reveal details about the shared history they have with their host planets.

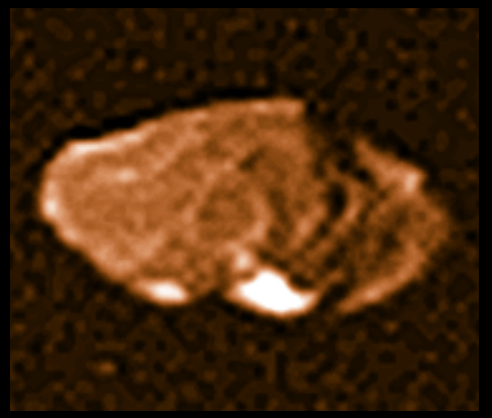


We speculate, from their irregular appearances and low mean densities, that Deimos and Phobos, are captured asteroids. Both Deimos and Phobos are saturated with craters. Deimos has a smoother appearance caused by partial filling of some of its craters.

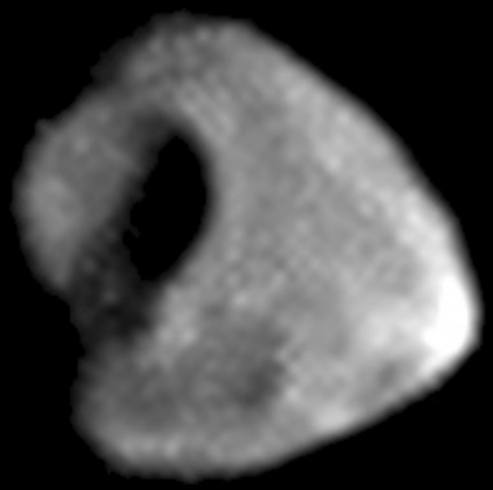
Moons of Jupiter



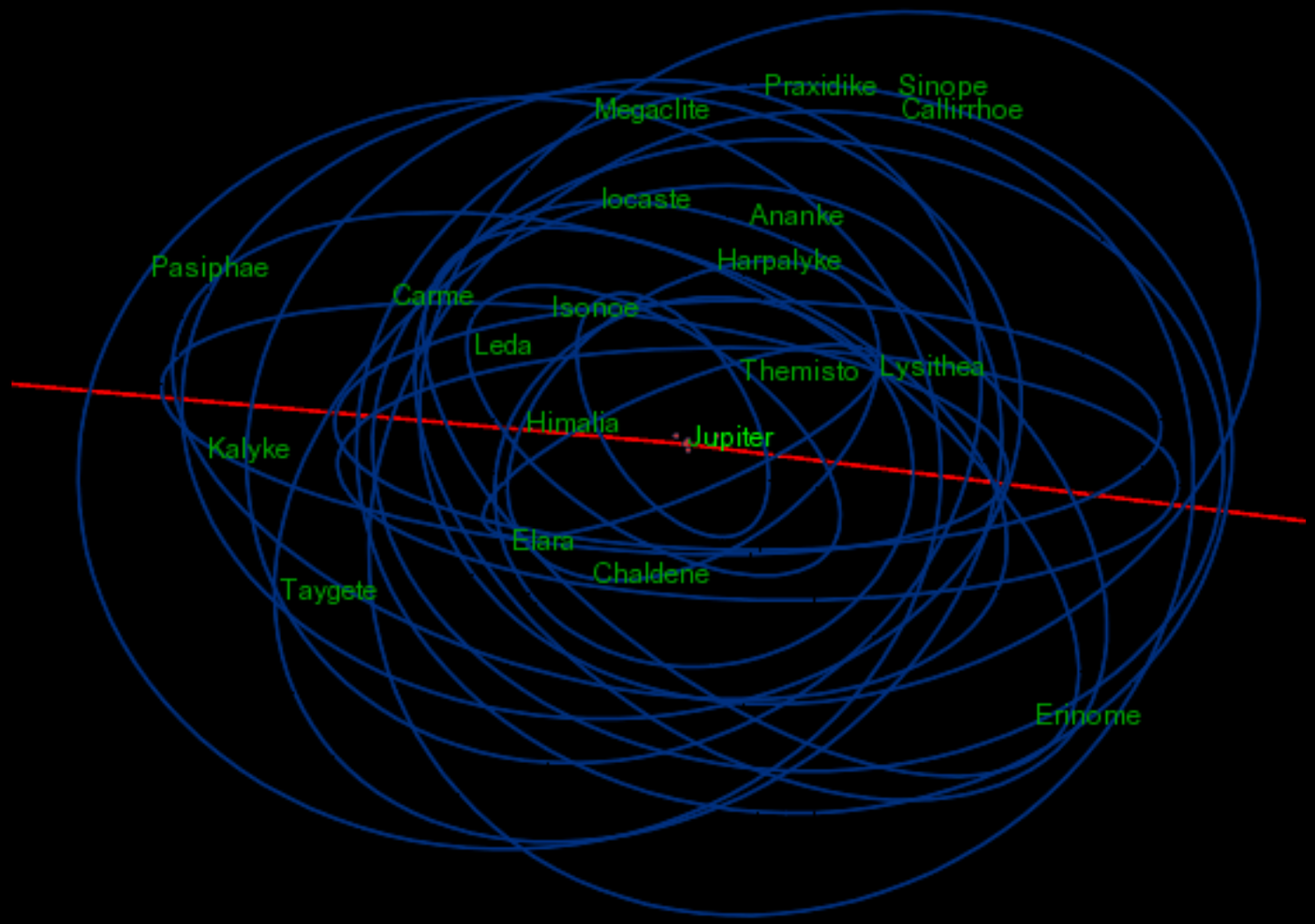
Metis



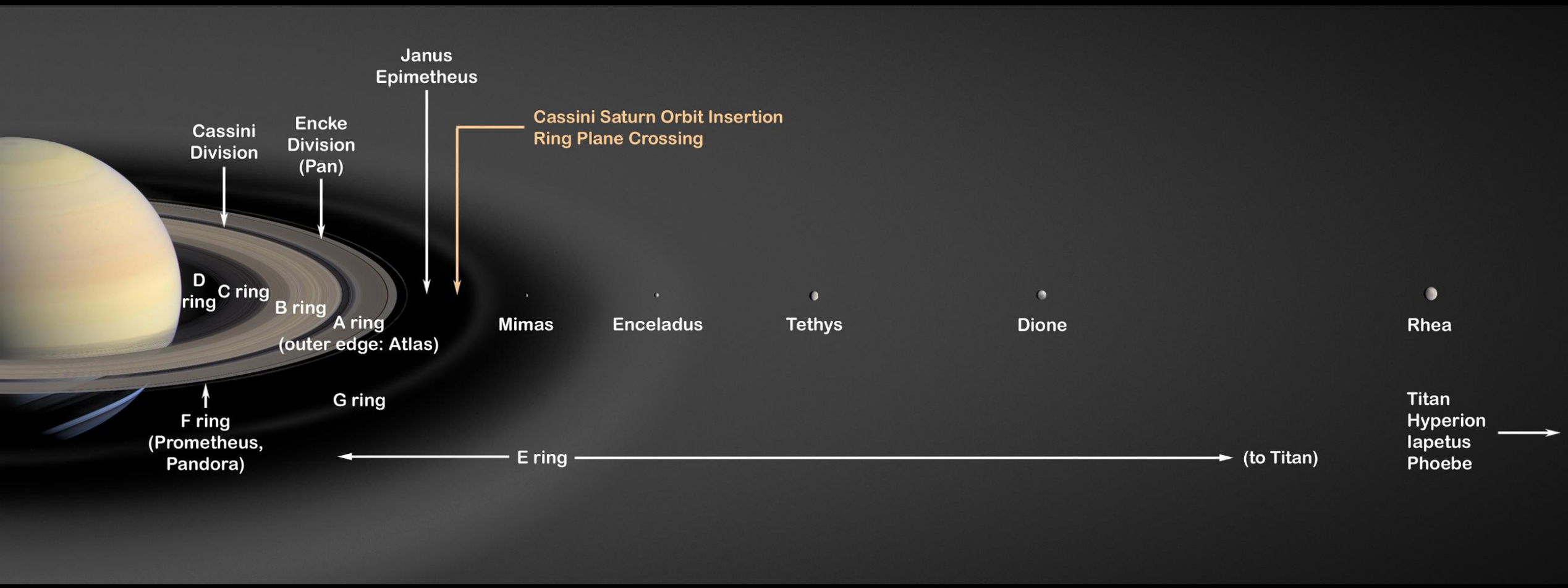
Amalthea



Thebe



Moons of Saturn



SATURN

Prometheus acts as a shepherding satellite, constraining the
extent of the inner edge of Saturn's F Ring.
It is extremely irregular with low density suggesting a porous, icy body.
Discovered in 1980 by the Voyager team
Distance from Saturn: 139,353 km (85,590 miles)
Mass: 1.9 x 1017 kg (4.18 x 1017 lbs)
Diameter: 148 x 100 x 68 km (92 x 62 x 42 miles)
Period of Orbit around Saturn: 14.7 hours

Pandora is cratered, the 2 largest ones are about 30 kilometers in diameter.
Less intrusive than her sibling shepherd moon, Pandora nonetheless provides a
gravitational influence that helps confine and perturb the F ring's shape.
Gravity is weak but it does hold onto the loose material formed by catering.
The mantle of fine debris partially hides older craters,
slowly covering and filling them as it coats the moon.
Discovered in 1980 by the Voyager team
Distance from Saturn: 141,700 km (88,048 miles)
Mass: 1.5 x 1017 kg (3.3 1017 lbs)
Diameter: 110 x 88 x 62 km (68 x 55 x 39 miles)
Period of Orbit around Saturn: 15.1 hours

Mimas [MY-muss] is made primarily of water-ice.
Its surface is heavily cratered, indicating that its impact
features may date back to the time of the moon's creation.
One of the craters, named Herschel, is surprisingly
large -- nearly one-third the moon's entire diameter.
Herschel is 10 kilometers deep, with a central mountain
that rises 6 kilometers (3.7 miles) above the crater floor.
Discovered in 1789 by William Herschel
Distance from Saturn: 185,520 km (115,277 miles)
Mass: 3.81 x 1019 kg (8.3 x 1019 lbs)
Diameter: 418 x 392 x 383 km (260 x 244 x 238 miles)
Period of Orbit around Saturn: 22.6 hours

Epimetheus is irregular and with extensive cratering
indicating that its surface must be several billion years old.
Epimetheus and Janus share the same orbit swapping positions every
few years -- one moving just a bit closer to Saturn and the other moving slightly farther away.
Discovered in 1966 by R. Walker
Distance from Saturn: 151,422 km (94,089 miles)
Mass: 5.3 x 1017 kg (11.68 x 1017 lbs)
Diameter: 138 x 110 x 110 km (86 x 68 x 68 miles)
Period of Orbit around Saturn: 16.7 hours
Closest approach: Dec. 3, 2007 -- 6,356 km (3,949 miles)

Janus is irregular with extensive cratering and few linear features.
It shares its orbital path with Epimetheus, and the two moons swap positions every
few years -- one moving just a bit closer to Saturn and the other moving slightly farther away.
Discovered in 1966 by Audouin Dollfus
Diameter of 194 x 190 x 154 km. (121 x 118 x 96 miles)
Mass: 1.90 x 1018 kg (4.19 x 1018 lbs)
Period of Orbit around Saturn: 16.7 hours
Distance from Saturn: 151,422 km (94,089 miles)
Closest approach: June 1, 2008 -- 14,363 kilometers (8,925 miles)

Atlas orbits around the outer edge of Saturn's A Ring, and acts
as a shepherding satellite, constraining the extent of the outer
edge of this ring.
discovered by Voyager in 1980 from photocgraphs taken.
Distance from Saturn: 137,670 km (85,544 miles)
Mass: 2 x 1015 kg (4.4 x 1015 lbs)
Diameter: 37 x 34.4 x 27 km (23 x 21.3 x 17 miles)
Period of Orbit around Saturn: 14.4 hours

Daphnis (S/2005 S1) orbits in the Keeler Gap within the A ring.
Discovered in May 2005 by the Cassini imaging team.
Distance from Saturn: 136,505 km
Mass: unknown
Diameter: approx. 7 km (4.3 miles)
Period of Orbit around Saturn: approx. 14.2 hours

Pan, the innermost of Saturn's known moons, is located
within the Encke Gap of Saturn's A-ring. It acts as
a shepherd satellite and is responsible for keeping the Encke gap open.
Discovered in 1990 by the Voyager team (by reexamining photos taken
nine years earlier near the predicted locations)
Distance from Saturn: 133,583 km (83,005 miles)
Mass: 5 x 1015 kg (11 x 1015 lbs)
Diameter: 20 km (12.5 miles)
Period of Orbit around Saturn: 13.8 hours

Methone (S/2004 S1)
Discovered in June 2004 by the Cassini imaging team
may be the same object that was spotted in a single image taken by
Voyager spacecraft in the '80s, at that time known as S/1981 S14.
Distance from Saturn: 194,000 km (120,546 miles)
Mass: unknown
Diameter: 3 to 4 km (about 2 - 2.5 miles)
Period of Orbit around Saturn: 24 hours

Pallene (S/2004 S2)
Discovered in June 2004 by the Cassini imaging team
Distance from Saturn: 211,000 km (about 131,100 miles)
Mass: unknown
Diameter: 4 km (2.5 miles)
Period of Orbit around Saturn: 26 hours
Closest approach: May 25, 2008 -- 19,536 kilometers (12,139 miles)

Telesto is known as a "Tethys Trojan" because, together with Calypso, it circles Saturn in
the same orbit as the moon Tethys, about 60 degrees ahead of and behind it.
While Telesto is the "leading Trojan," Calypso is the "trailing Trojan."
The smooth surface of this moon suggests that, like Pandora, it is covered with
a mantle of fine, dust-sized icy material.
Discovered in 1980 using ground-based observations by Brad Smith,
Harold Reitsema, Stephen Larson and John Fountain
Mass: 8 x 1017 kg (17.6 x 1017 lbs)
Equatorial diameter: 30 x 25 x 15 km (19 x 15.5 x 9 miles)
Distance from Saturn: 294,660 km (about 183,090 miles)

Tethys is composed almost entirely of water-ice.
Its icy surface is heavily cratered.The enormous
trench called Ithaca Chasma, approximately 65 km wide and
4 km deep, runs across over 1000 km and was probably
caused by the moons' liquid crust hardening before its interior.
Discovered in 1684 by Giovanni Cassini
Distance from Saturn: 294,660 km (183,093 miles)
Density: 1.21 gm/cm3
Diameter: 1,071 x 1,056 x 1,052 km (665 x 656 x 654 miles)
Mass: 6.17 x 1020 kg (13.60 x 1020 lbs)

Calypso is known as a "Tethys Trojan" because it circles Saturn
in the same orbit as Tethys, about 60 degrees ahead of and behind it.
While Telesto is the "leading Trojan," Calypso is the "trailing Trojan."
Although the resolution here is not as high as those of Pandora and Telesto,this
moon appears to also have loose surface material capable of smoothing the appearance of craters.
Discovered in 1980 using ground-based observations by Brad Smith,
Harold Reitsema, Stephen Larson and John Fountain
Mass: 8 x 1017 kg (17.6 x 1017 lbs)
Equatorial diameter: 30 x 16 x 16 km (19 x 10 x 10 miles)
Distance from Saturn: 294,660 km (183,093 miles)

Polydeuces is the trailing co-orbital Trojan moon of Dione,
while the moon Helene is the leading co-orbital.
It is believed that Polydeuces can get as close as 39 degrees to Dione
and then drift as far as 92 degrees from over a 2 year period.
Discovered in October 2004 by the Cassini imaging team
Mass: Unknown
Equatorial diameter: 13 km (8 miles)
Distance from Saturn: 377,400 Km. (about 234,500 miles)

Enceladus [en-SELL-ah-dus] is one of the brightest objects in our solar system.
Covered in water ice reflecting almost 100 percent of the sunlight that strikes the surface.
The temperature is therefore extremely cold, about -201° C (-330° F).
Near the south pole are long, roughly parallel dark markings. From these
fractures,called sulci, a spray of icy particles escapes into the void, forming Saturn's E ring.
Parts of the moon show craters no larger than 35 kilometers (about 22 miles) in diameter.
Other areas show regions with no craters indicating major resurfacing events in the geologica
There are fissures, plains, corrugated terrain and other crustal deformations.
All of this indicates that the interior may be liquid today, even though it should have been froz
Recent studies in fact show that tidal forces acting on fault lines in the moon's icy shell cause
faults, the “tiger stripes”, to rub back and forth against each other, producing enough
heat to transform some of the ice into plumes of water vapor and ice crystals,
Unlike some other proposals for the origin of the plumes, this mechanism does not require the presence of liquid water
near the surface, The surface is believed to be geologically “young,” possibly less than 100 million years old.
Discovered in 1789 by William Herschel
Distance from Saturn: 237,378 kilometers (147,500 miles)
Mass: 1.2 x 1020 kg (2.6 x 1020 lbs)
Diameter: 512 x 494 x 489 km (318 x 307 x 304 miles)
Period of Orbit around Saturn: 32.8 hours
Next close flyby: March 12, 2008 -- 23 kilometers (14 miles)

Dione is the second dense
Saturn after Titan. It is probably c
of a rocky core making for one-thir
mass,and the rest is composed of w
Dione was discovered in 1684 by Gio
Distance from Saturn: 377,400 km
Density of 1.43 gm/cm3
Mass: 1.10 x 1021 kg
Equatorial diameter: 1,118 km (695 m

Helene is a Trojan moon, sharing Dione's orbit but staying
or 400,000 kilometers ahead of the much larger moon.
Discovered by P. Laques and J. Lecacheus in 1980
Mass: 8 x 1017 kg (17.6 x 1017 lbs)
Equatorial Diameter: 36 x 32 x 30 km (22 x 19 x 18.6 miles)
Distance from Saturn: 377,400 km (234,505 miles)

Rhea is the largest airless satellite in the Saturnian system. It is an icy body with a low density, which indicates that it is composed of a rocky core taking up less than one-third of the moon's mass, with the rest composed of water-ice.
Rhea is heavily cratered with bright wispy markings. Its surface can be divided into two geologically different areas based on crater density. The first area contains craters that are larger than 40 kilometers (25 miles) in diameter. The second area, spanning over parts of the polar and equatorial regions, has smaler craters suggesting that a major resurfacing event occurred some time during its formation.
Discovered in 1672 by Giovanni Cassini
Mass: 2.31 x 1021 kg (5.09 x 1021lbs)
Equatorial diameter: 1,528 km (949 miles)
Distance from Saturn: 527,040 km (327,487 miles)

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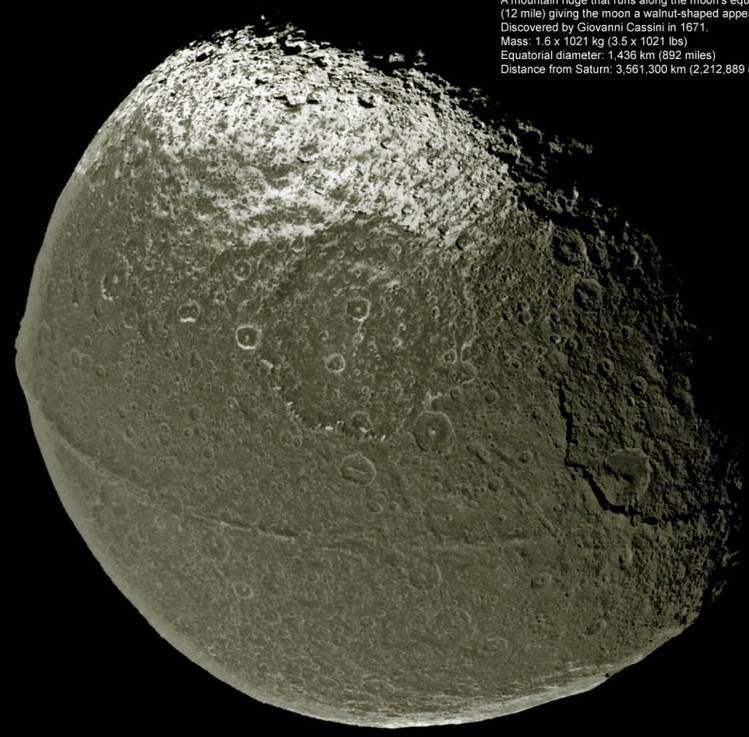
Titan [TIE-tun] may contain fundamental clues to the question of how life began on Earth for it may preserve, in deep-freeze, many of the chemical compounds that preceded life on Earth.
Titan is the largest of Saturn's moons, bigger than the smallest planet, Mercury. It is also the only moon in the solar system that possesses a dense atmosphere (10 times denser than Earth's).
Titan is a dynamic place with complex geologic processes.
Discovered in 1655 by Christiaan Huygens
Distance from Saturn: 1,221,850 kilometers (759,220 miles)
Period of orbit around Saturn: 15.945 days
Temperature at surface: 95 Kelvin (-178º C, -288º F)
Mass: 1.34 x 1023 kilograms (2.95 x 1023 lbs)

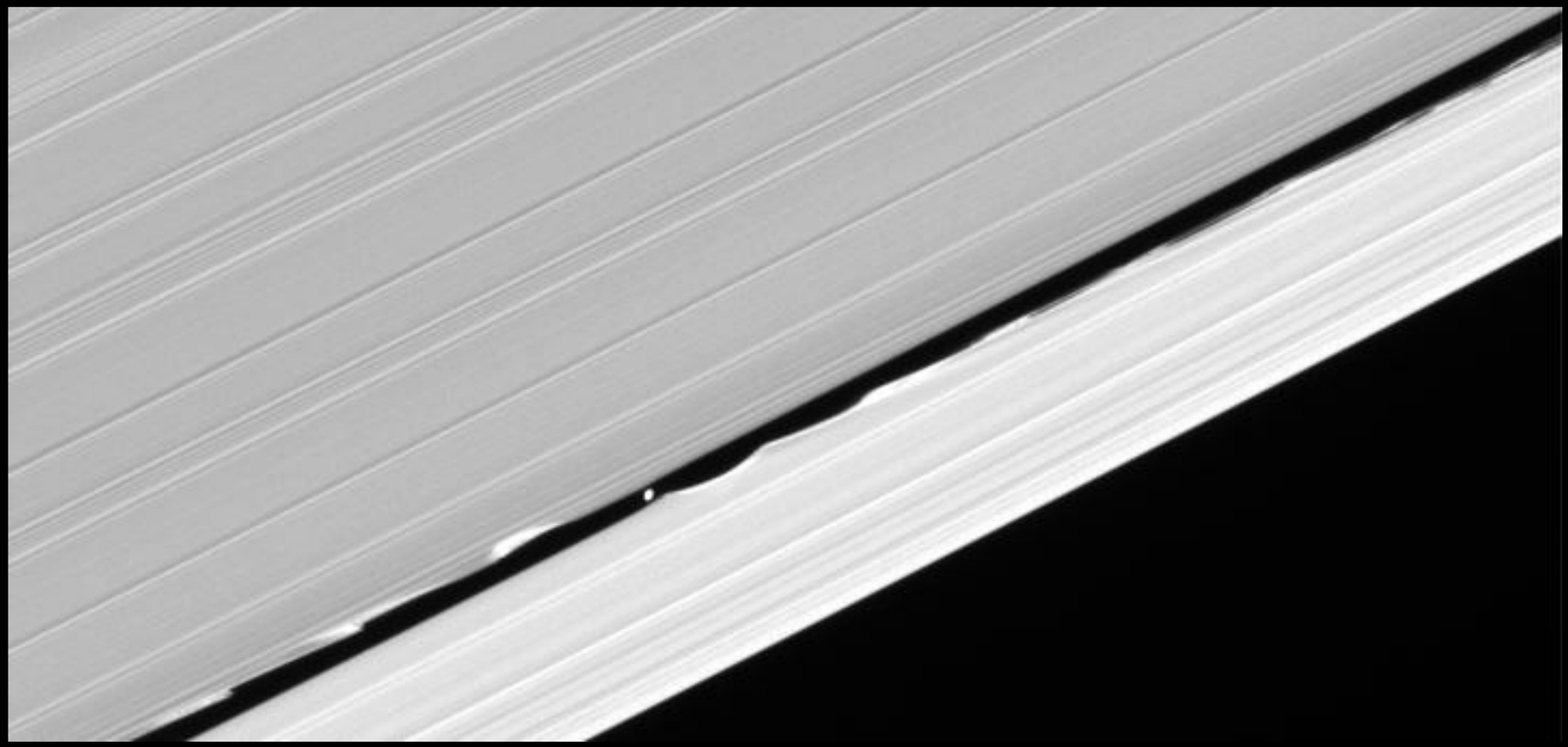


Iapetus (eye-AP-eh-tuss) is nicknamed the yin-yang of the solar system.
Half of Iapetus appears as dark as asphalt (the "Cassini Regio"), the other half, as bright as snow. Scientists generally believe that it has swept up the orbiting dark material (perhaps originally from Phoebe)
A mountain ridge that runs along the moon's equator is 20-kilometer high (12 mile) giving the moon a walnut-shaped appearance.
Discovered by Giovanni Cassini in 167'1.
Mass: 1.6 x 1021 kg (3.5 x 1021 lbs)
Equatorial diameter: 1,436 km (892 miles)
Distance from Saturn: 3,561,300 km (2,212,889 miles)

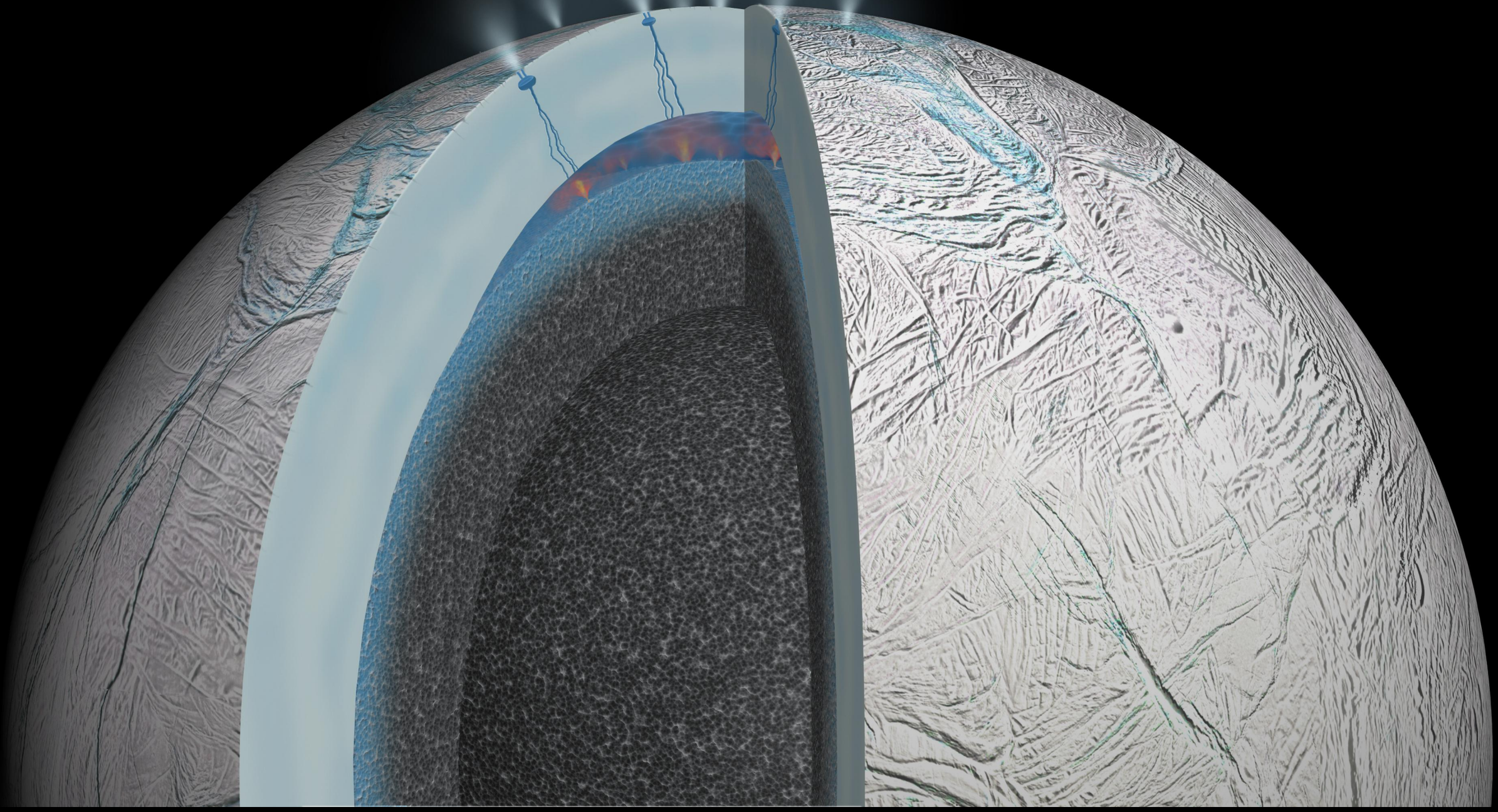
Phoebe (FEE-bee) is roughly spherical and rotates on its axis every nine hours.
Its irregular, elliptical orbit is inclined about 30 degrees to Saturn's equator.
Phoebe's orbit is also retrograde, which means it goes around Saturn the opposite direction than most other moons -- as well as most objects in the solar system.
Unlike most major moons orbiting Saturn, Phoebe is very dark and reflects only 6 percent of the sunlight it receives. Its darkness and irregular, retrograde orbit suggest
Phoebe is most likely a captured object. Some scientists think Phoebe could be a captured Centaur.
Centaurs are believed to be Kuiper Belt bodies that migrated into the inner solar system.
Centaurs a kind of intermediate type of small body, neither an asteroid nor a Kuiper Belt object.
Phoebe might never have heated up enough to change its chemical composition.
Discovered in 1898 by William Pickering
Distance from Saturn: 12,952,000 km (about 8,048,000 miles)
Mass: 4 x 1017 kg (6.8 x 1017 lbs)
Diameter: 220 kilometers (137 miles)
Period of orbit around Saturn: about 18 months.

Very little is known on the other outer moons (all discovered after the year 2000)

Hyperion is the largest irregularly shaped natural satellite ever observed, even though it is one of the smaller moons of Saturn.The largest crater on its surface is approximately 120 kilometers in diameter and 10 kilometers (6 miles) deep.
Unlike most of the dull grey moons in the Solar System, Hyperion's color is a rosy tan
Some scientists suspect the color comes from falling debris from moons farther out.
A similar origin has been suggested for the dark reddish material on Saturn's moon Iapetus.
Discovered in 1848 by W. and G. Bond (Cambridge, MA) and by W. Lassell (Liverpool)
Mass: 8 x 1017 kg (17.6 x 1017 lbs)
Equatorial diameter: 360 x 280 x 225 km (223 x 174 x 140 miles)
Distance from Saturn: 1,481,100 km (920,312 miles)



At least 150 moonlets embedded in the rings have been detected by the disturbance they create in the surrounding ring material, though this is thought to be only a small sample of the total population of such objects.

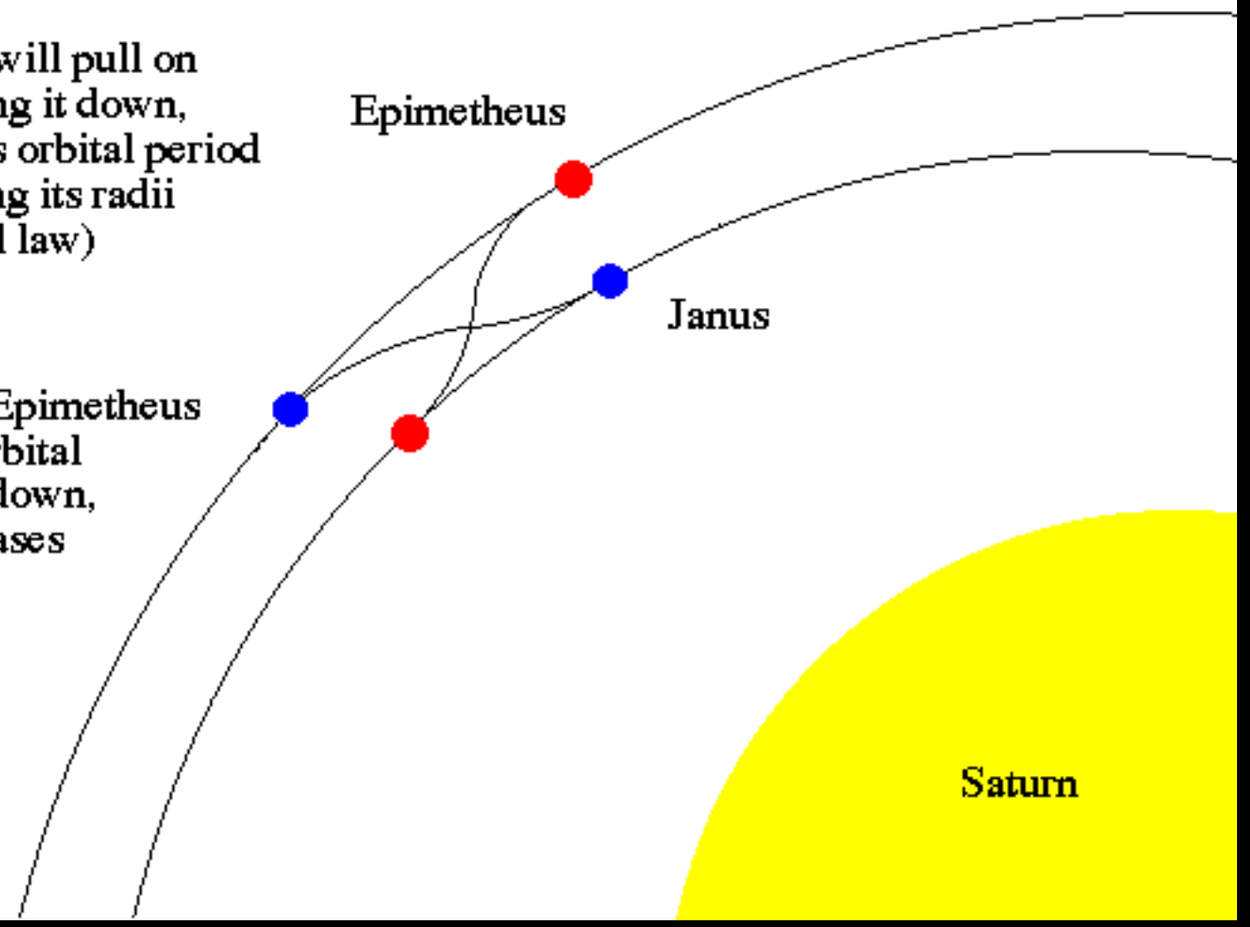


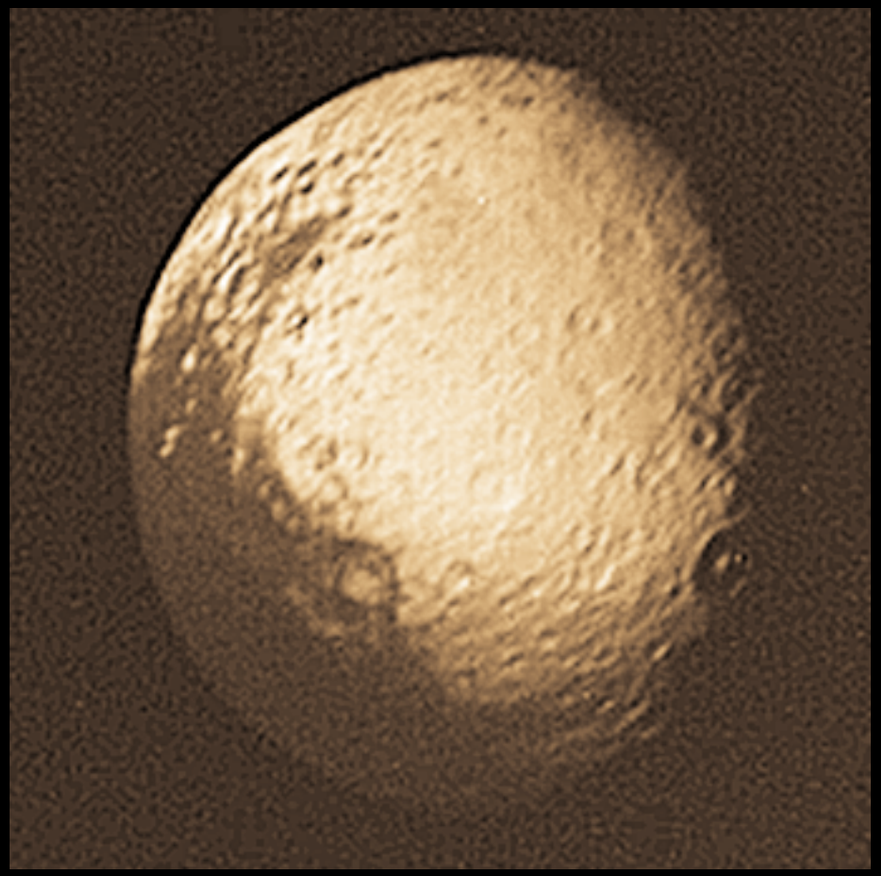
Enceladus is one of the smallest of Saturn's moons that is spherical in shape-only yet is the only small Saturnian moon that is currently endogenously active, and the smallest known body in the Solar System that is geologically active today.

Epimetheus and Janus travel in orbits separated by only 50km, and actually exchange places every few years.

Epimetheus will pull on Janus, slowing it down, increasing its orbital period and increasing its radii (Kepler's 3rd law)

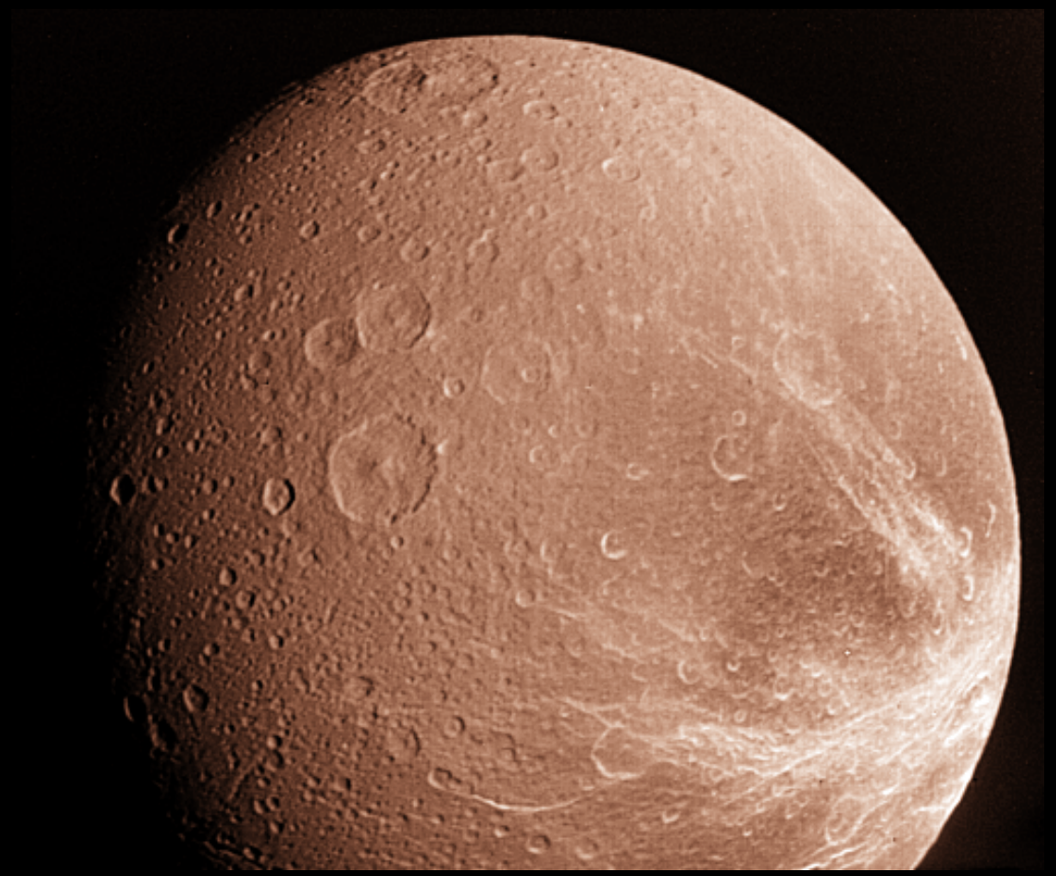
meanwhile, Epimetheus speeds up, orbital period goes down, radius decreases

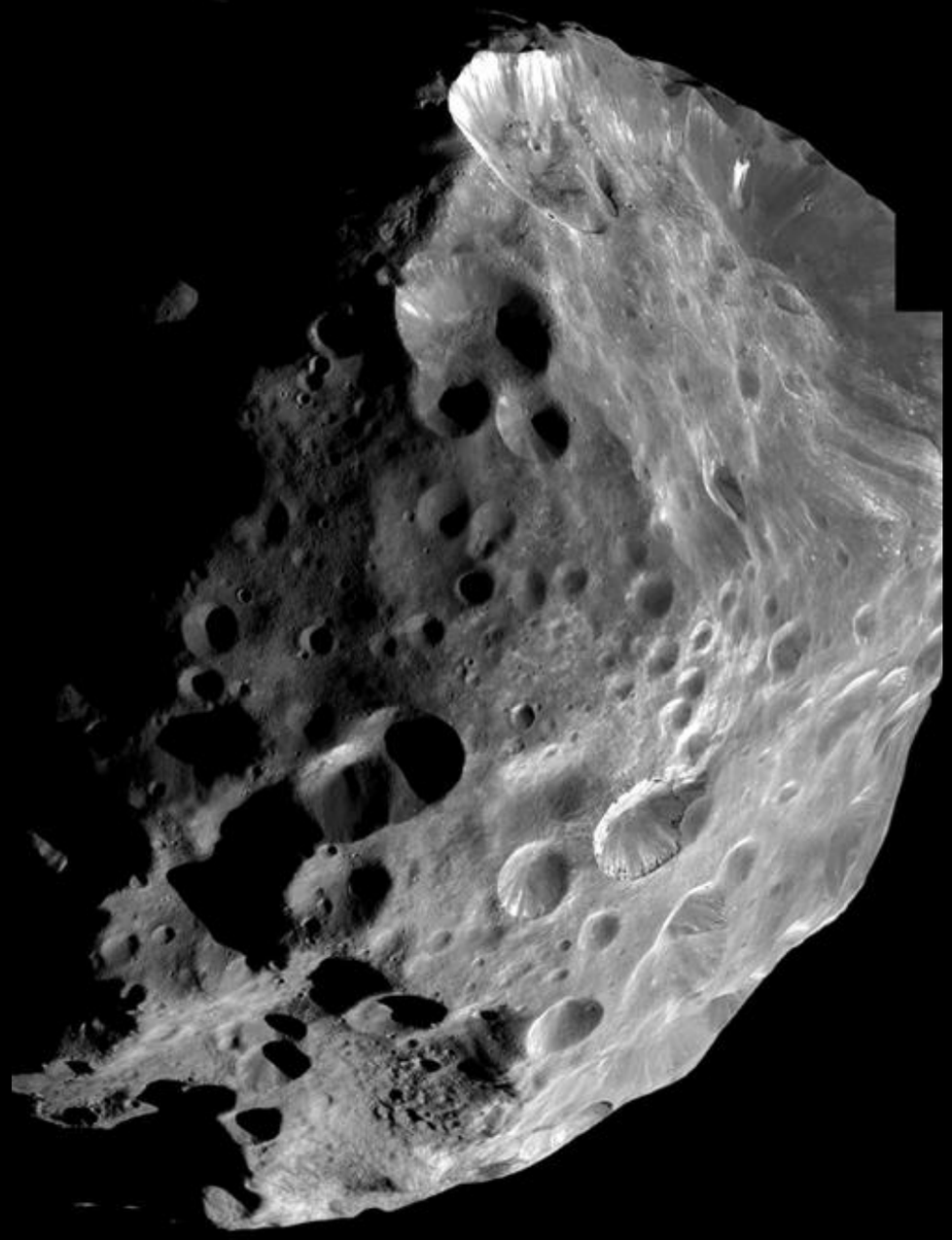




Iapetus is the third-largest of Saturn's moons. Orbiting the planet at 3.5 million km, it is by far the most distant of Saturn's large moons, and also has the largest orbital inclination, at 15.47 degrees. Iapetus has long been known for its unusual two-toned surface; its leading hemisphere is pitch-black and its trailing hemisphere is almost as bright as fresh snow.

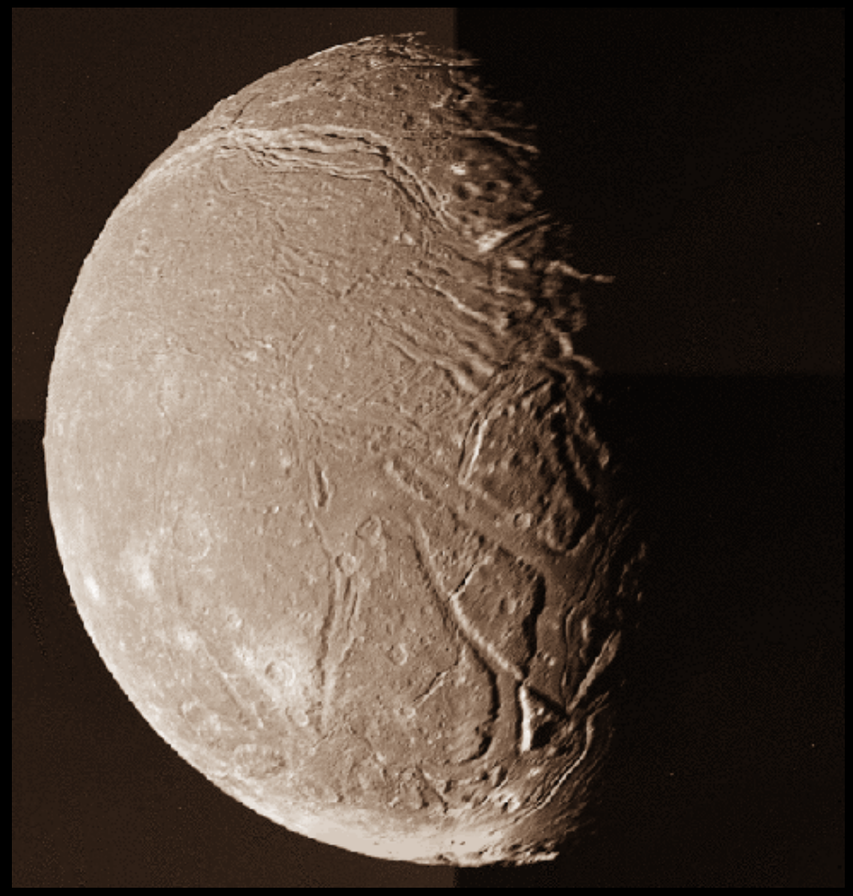
Dione is the densest moon of Saturn other than Titan, and has several usual characteristics: 1) has a rocky core and ice crust, 2) is heavy cratering on trailing hemisphere, 3) has bright, wispy features.





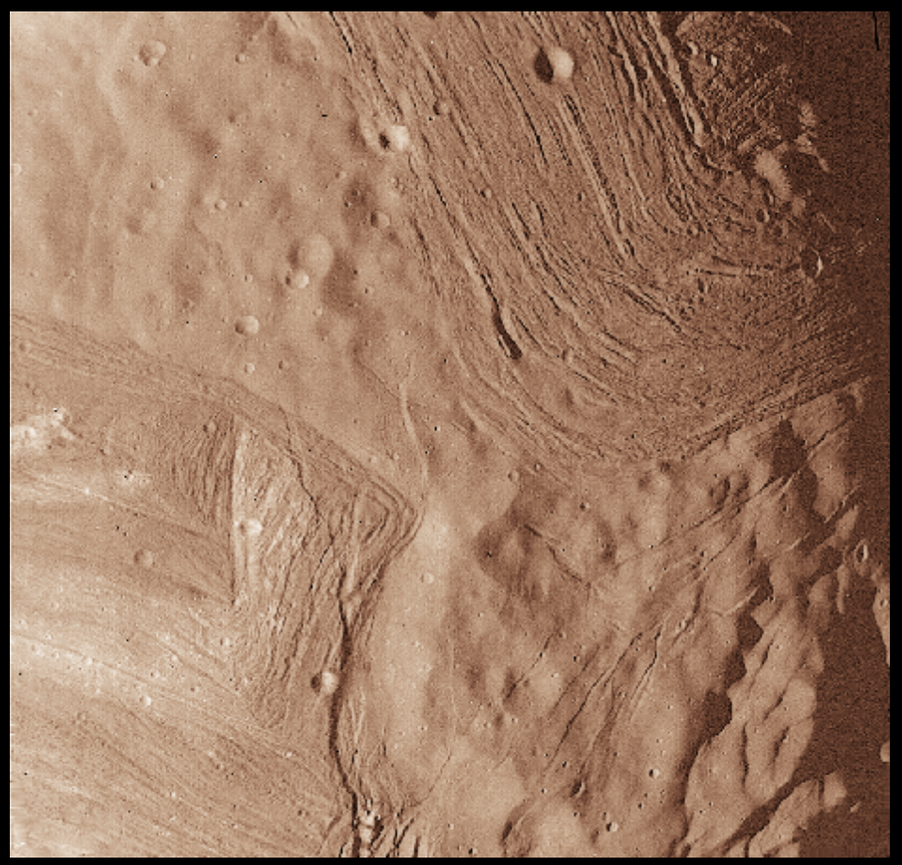
Phoebe is the last of the known satellites of Saturn and orbits in a retrograde direction (opposite to the direction of the other satellites' orbits) in a plane much closer to the ecliptic than to Saturn's equatorial plane. Thus, Phoebe may be a captured asteroid with a composition unmodified since the time it was formed in the outer Solar System.

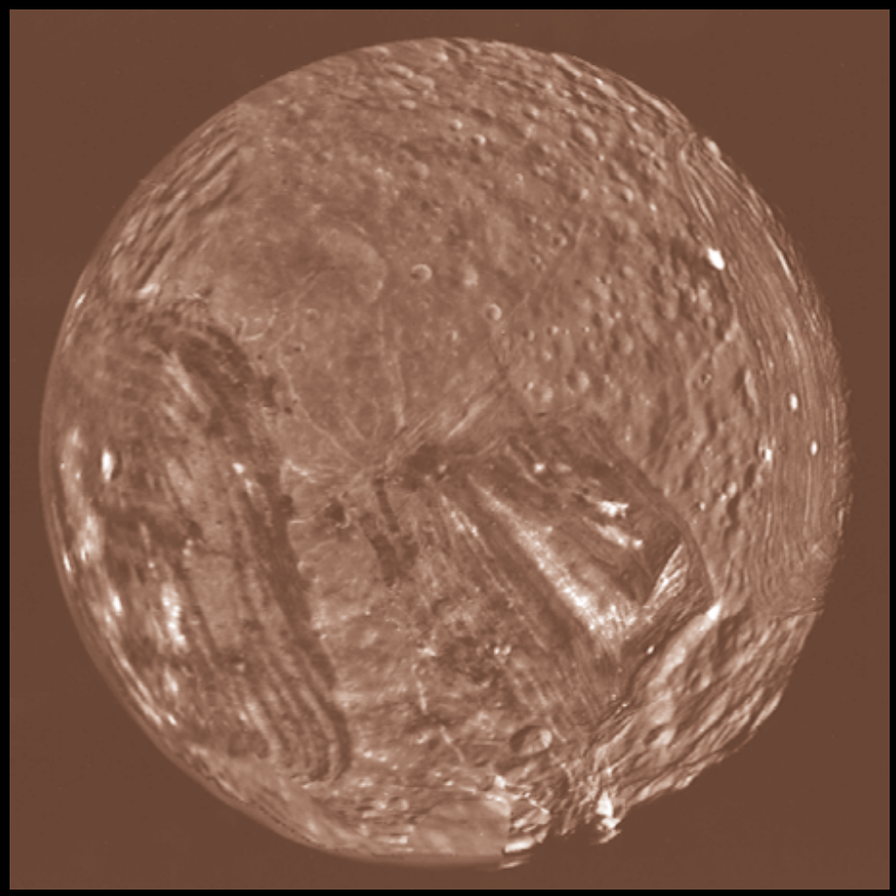
A montage of Uranus' large moons and one smaller moon: from left to right Puck, Miranda, Ariel, Umbriel, Titania and Oberon.

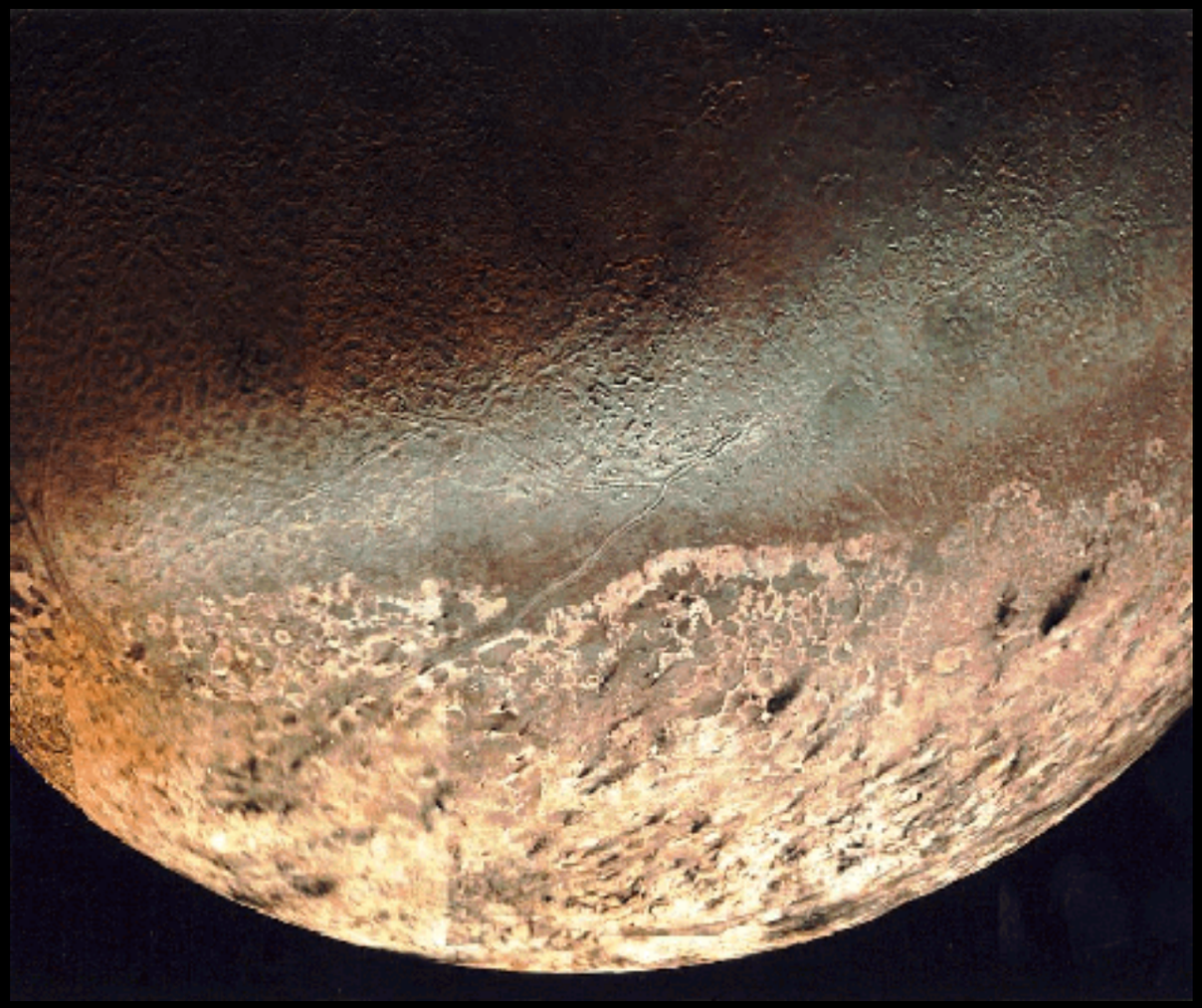


Ariel is a relatively small satellite and is the brightest moon of Uranus

Miranda is one of the satellites of Uranus with a diameter of 470 kilometers.It is believed that Miranda may have been shattered as many as five times during its evolution. After each shattering the moon would have reassembled from the remains of its former self with portions of the core exposed and portions of the surface buried.







Unique among all large planetary moons, Triton is an irregular satellite of Neptune, as its orbit is retrograde to Neptune's rotation and inclined relative to the planet's equator. The next-largest irregular satellite in the Solar System, Saturn's moon Phoebe, is only 0.03% Triton's mass. Triton is massive enough to have achieved hydrostatic equilibrium and to retain a thin atmosphere capable of forming clouds and hazes.

Six Moons Most Likely to Harbor Life

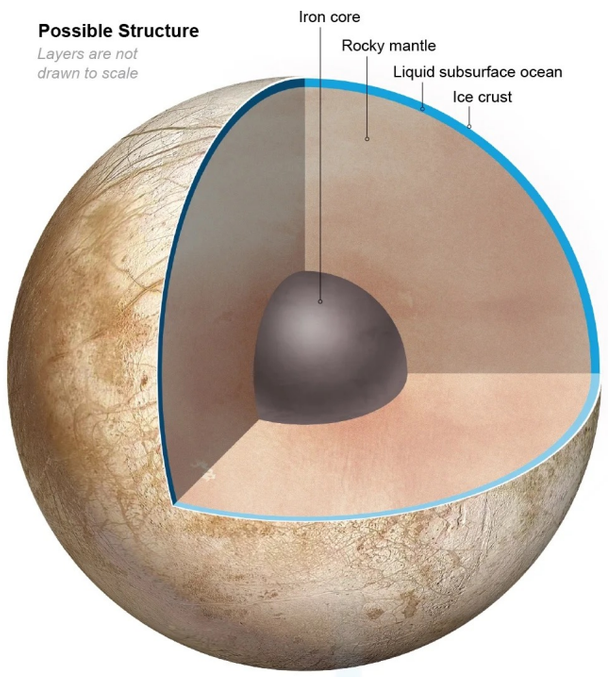
"The outer solar system is probably replete with moons that could have liquid water oceans on them, and a subset could have geothermal and water-rock interactions on the bottom," says Chris German, an oceanographer at the Woods Hole Oceanographic Institution, who is co-leading a NASA-funded initiative called Network for Ocean Worlds (NOW). Why do those characteristics matter? "Everywhere that has those on our planet gets colonized by microbial life," German says.

Life could flourish in half-frozen slush on Europa and Enceladus, within the subsurface saltwater ocean of Ganymede, underneath the methane and ethane rivers of Titan, and maybe in brines in the deepest craters of the dwarf planets Ceres and Pluto. The icy shells of the ocean worlds may even contain pores filled with liquid water—and perhaps microbes

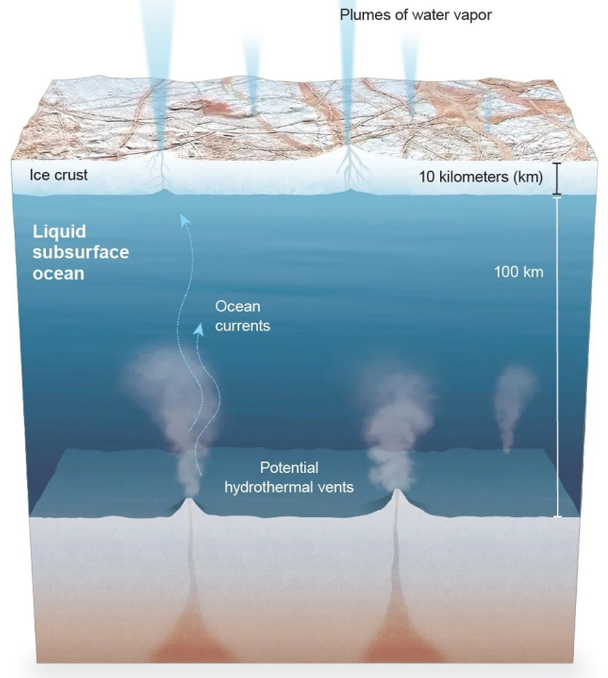
The moons in our solar system might contain several layers of rock, water and exotic high-pressure ices. Interactions between rock and water are fundamental to microbial diversity on Earth.

Europa

Strong evidence of liquid-saltwater subsurface ocean



Blocks of ice may be rafting on top of an ocean slurry. The rocky seafloor may be covered in high-pressure ice-VII, which forms a cubic crystalline structure, unlike the hexagonal water ice on Earth. Ice-VII can efficiently transport salts, so it could support chemical interactions that could energize a web of life.



Ocean Volume (billions of km³) 1.8 Earth, 2.6 Europa

Surface Temperature –225 °F

Diameter 3,130 km

Explored by **1970s:** Flybys of Pioneer 10, Pioneer 11, Voyager 1, Voyager 2
1996: Galileo

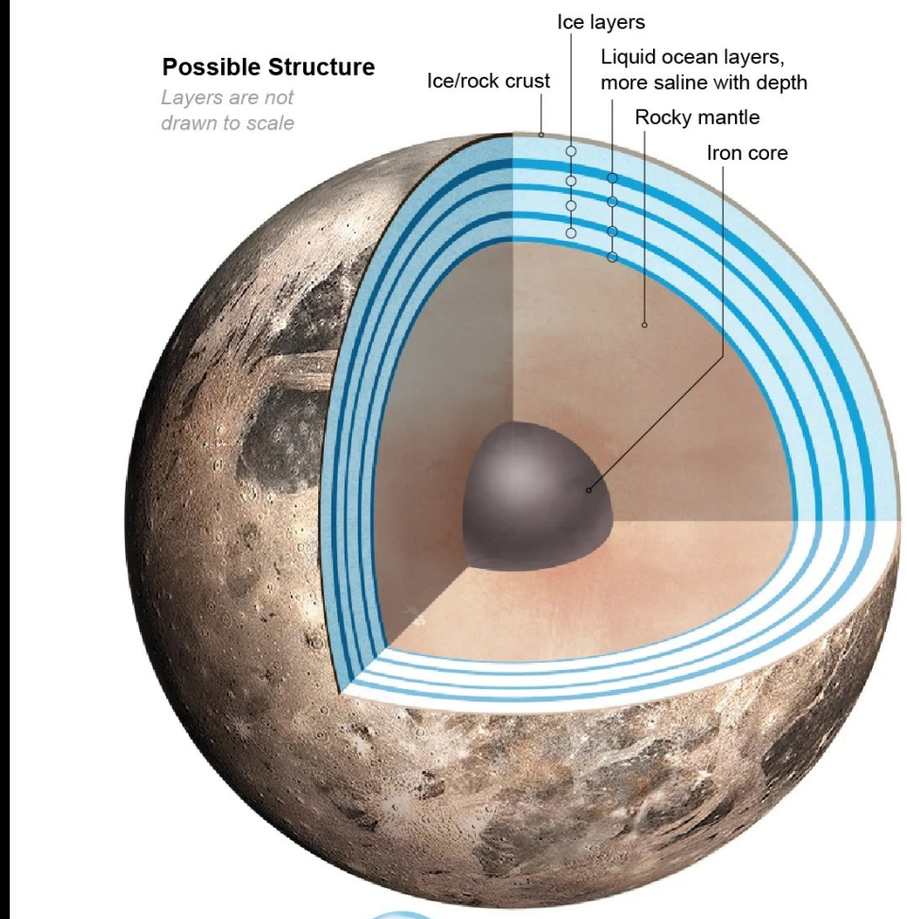
Planned Missions **April 2023:** European Space Agency's JUICE
2024: NASA's Europa Clipper

What We Still Don't Know

The Hubble Space Telescope saw fleeting evidence of water plumes escaping Europa through cracks in its icy shell. The upcoming

Ganymede

Strong evidence of liquid-saltwater subsurface ocean



Ocean Volume (billions of km³) 1.8 Earth, 37.8 Ganymede

Surface Temperature –297 °F to –171 °F

Diameter 5,262 km

Discovered 1610 by Galileo Galilei

Explored by **1970s:** Flybys of Pioneer 10, Pioneer 11, Voyager 1 and Voyager 2
1996: Galileo
2000: Cassini
2021: Juno

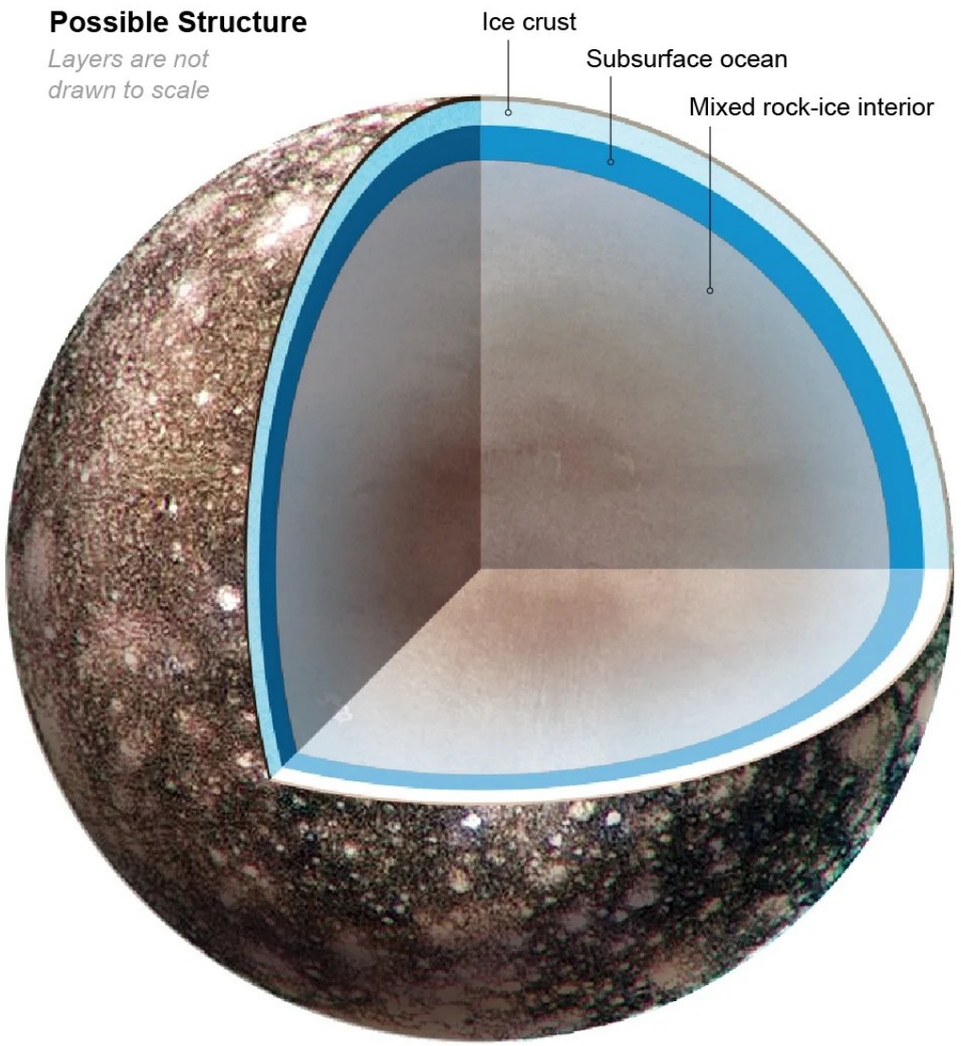
Planned Missions **April 2023:** European Space Agency's JUICE

What We Still Don't Know

Ganymede is the JUICE mission's primary target. Scientists will use the spacecraft to try to determine the source of the moon's magnetic field and to study details about its auroras.

Callisto

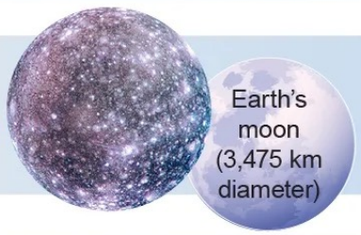
Potential liquid subsurface ocean



Ocean Volume (billions of km³) 1.8 Earth · 4.8 Callisto

Surface Temperature –218 °F

Diameter 4,820 km



Discovered 1610 by Galileo Galilei

Explored by 1970s: Flybys of Pioneer 10, Pioneer 11, Voyager 1 and Voyager 2
1996: Galileo

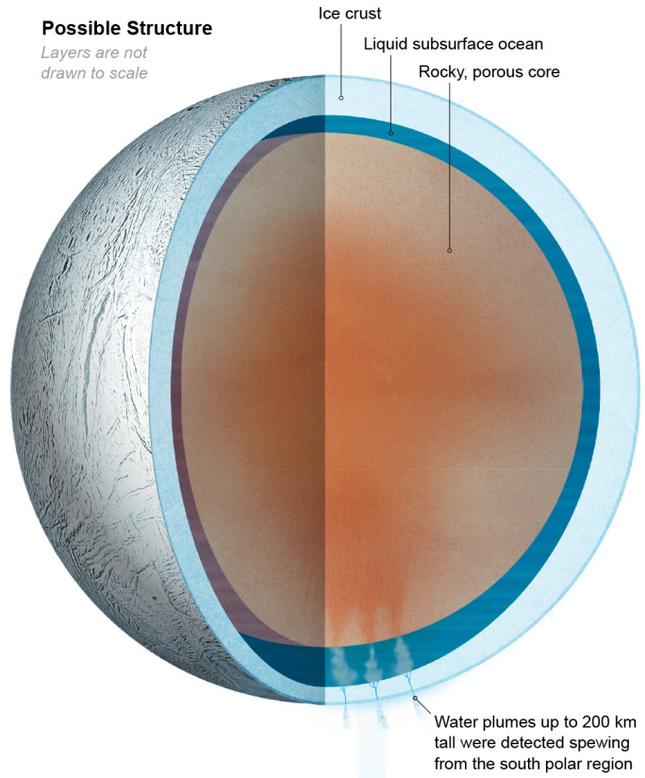
Planned Missions April 2023: European Space Agency's JUICE

What We Still Don't Know

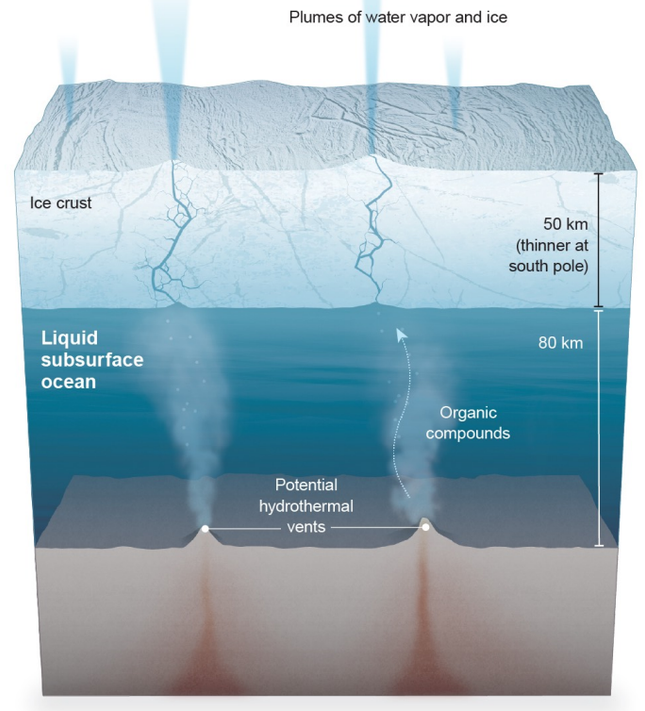
Scientists are split on whether Callisto hosts an underground saltwater ocean and how deep it would be. By using JUICE to study the moon's shape and its gravity field, scientists hope to settle this debate.

Enceladus

Strong evidence of liquid-saltwater subsurface ocean



Plumes of ejecta from cracks in Enceladus's shell feed Saturn's E ring, which contains ice and silica grains that form only in interactions between warm water and rock. Their existence hints at hydrothermal vents under Enceladus's ocean, which might be similar to those on Earth's seafloor.



Ocean Volume (billions of km³) 1.8 Earth · 0.01 Enceladus

Surface Temperature –330 °F

Explored by 1980-81: Flybys by Voyager 1 and Voyager 2
2005: Cassini

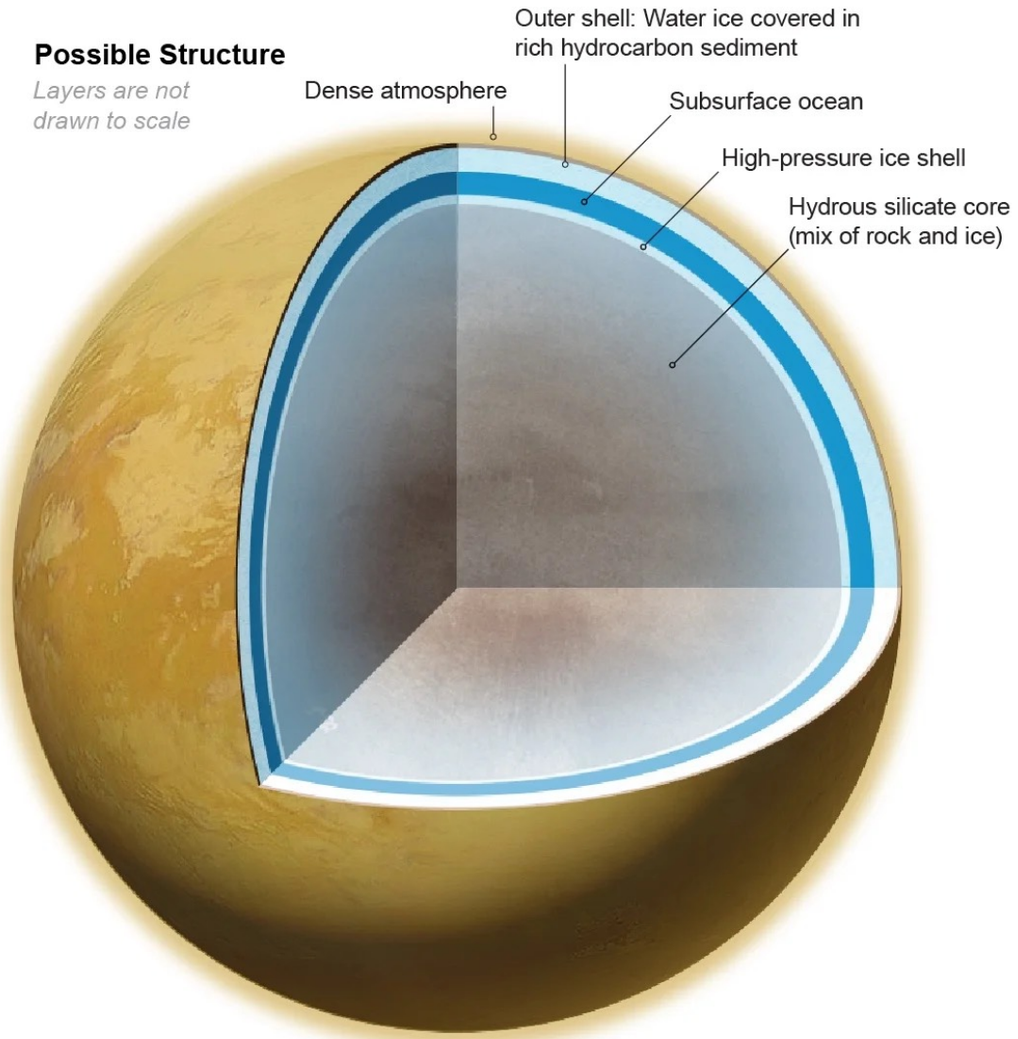
Planned Missions Enceladus Orbilander concept by Johns Hopkins Applied Physics Laboratory would orbit and then land in search for potential life

Titan

Strong evidence of liquid subsurface ocean

Possible Structure

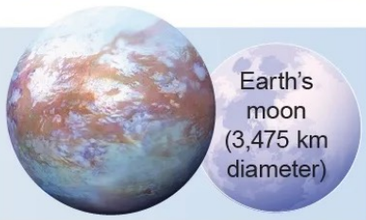
Layers are not drawn to scale



Ocean Volume (billions of km³) 1.8 Earth, 17.0 Titan

Surface Temperature −290 °F

Diameter 5,152 km



Discovered 1655 by Christiaan Huygens

Explored by 1980-81: Flybys by Voyager 1 and Voyager 2
2005: Cassini-Huygens (Cassini flybys and Huygens probe landing)

Planned Missions Mid-2030s: Dragonfly is set to launch in 2027 and arrive in 2034

What We Still Don't Know

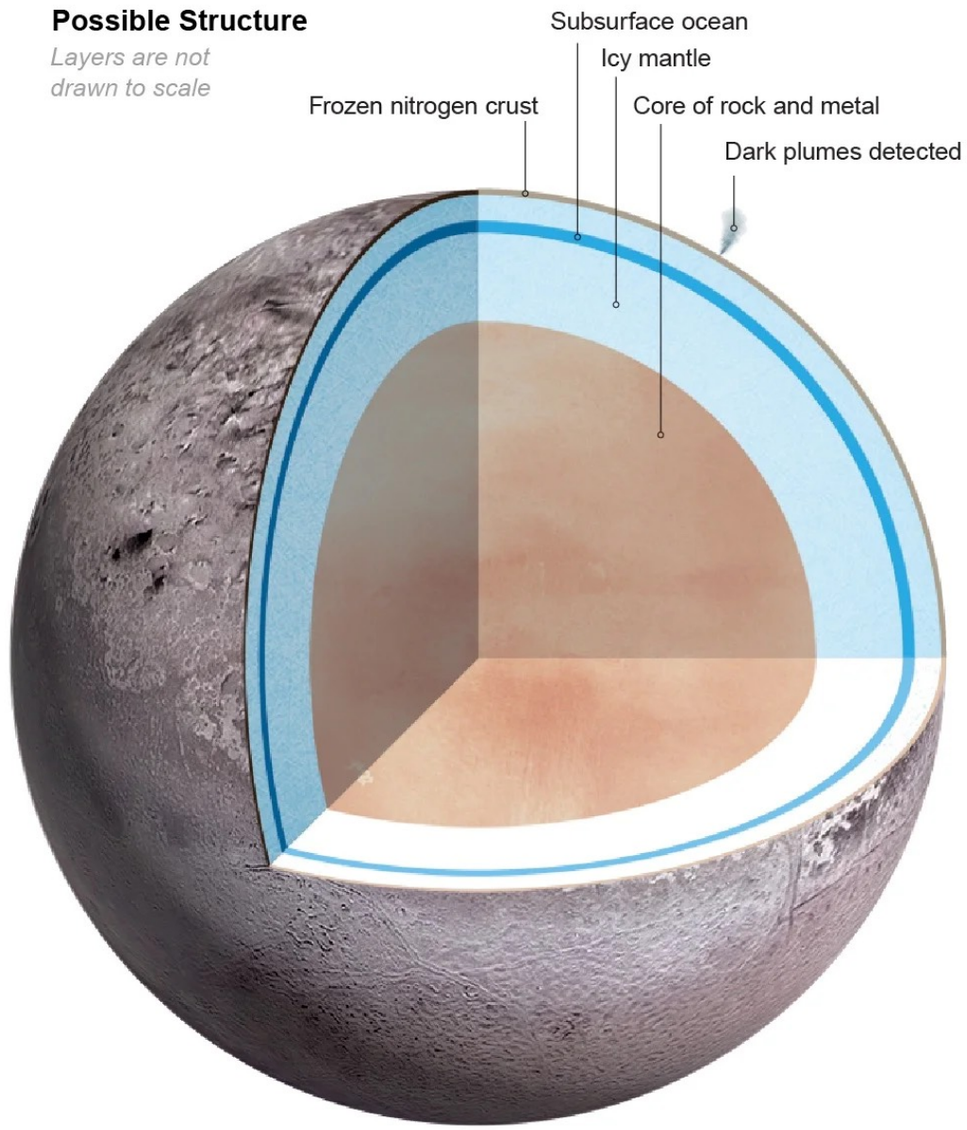
One theory for why Titan hosts so much methane—which continually breaks down in sunlight—is that methane might erupt from cryovolcanoes that ooze chilled water instead of molten rock.

Triton

Hypothesized liquid subsurface ocean

Possible Structure

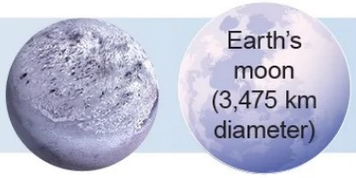
Layers are not drawn to scale



Ocean Volume (billions of km³) 1.8 Earth, 0.03 Triton

Surface Temperature −391 °F

Diameter 2,704 km



Discovered 1846 by William Lassell

Explored by 1989: Flyby by Voyager 2

Planned Missions None planned so far

What We Still Don't Know

Voyager 2 glimpsed evidence of geysers and lavalike flows above Triton's surface, suggesting the presence of an ocean under a geologically active, icy crust. A closer look would help explain what is going on.