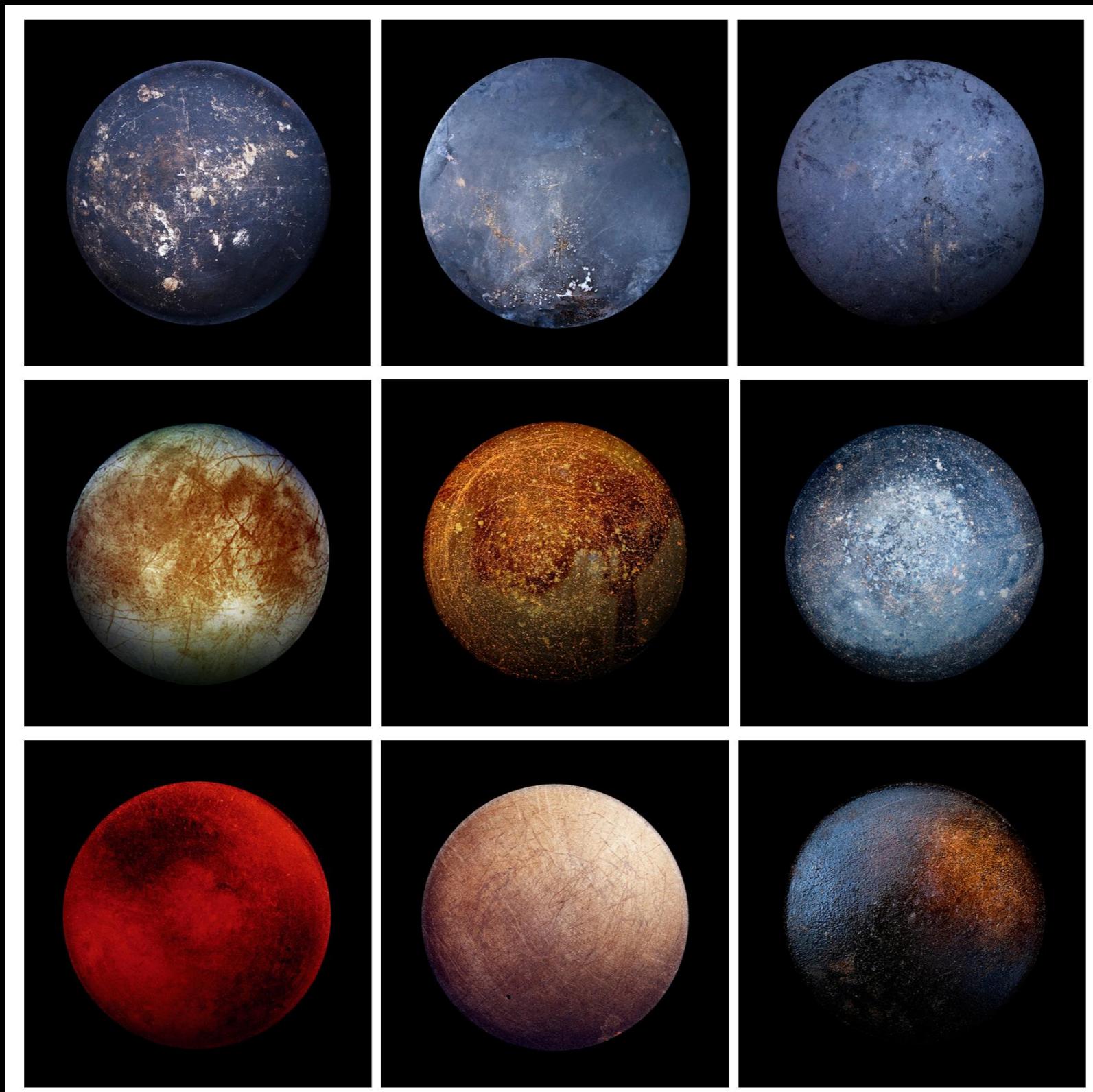
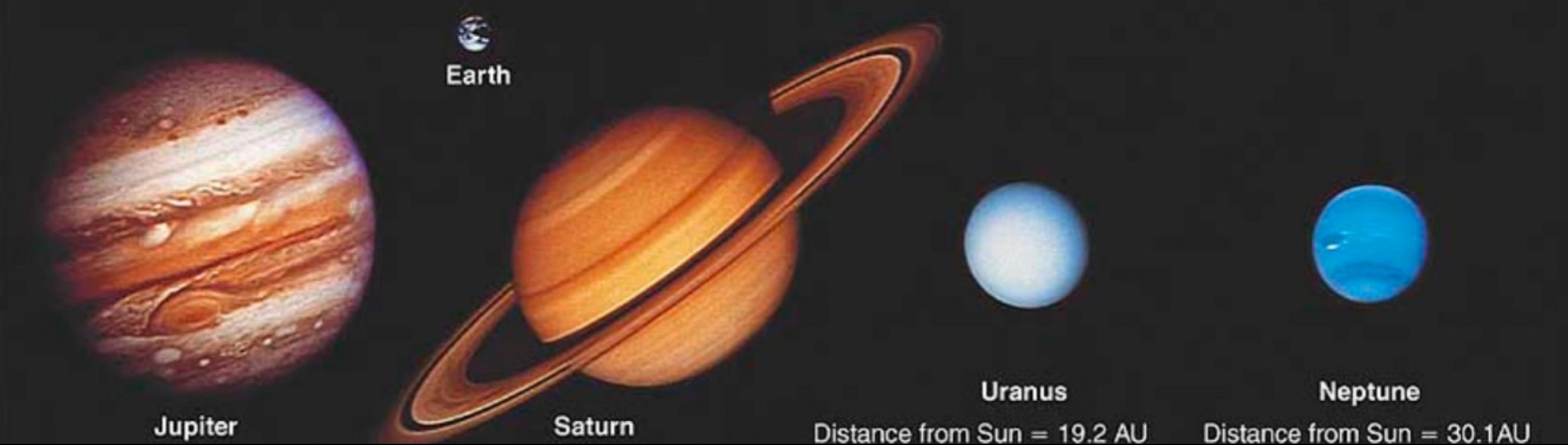


One of these is a moon of Jupiter...



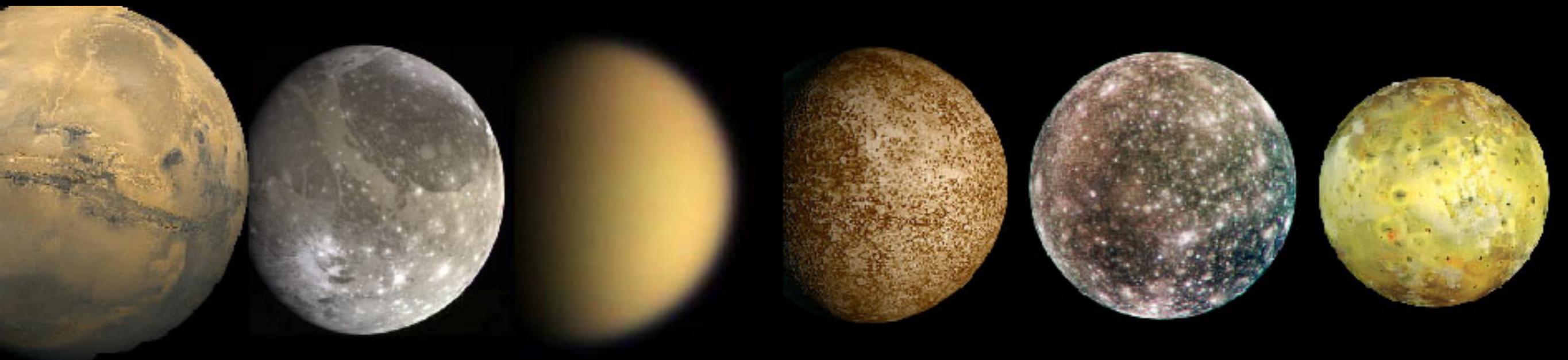
...the rest are frying pans!

# Comparing the giant planets



Property	Jupiter	Saturn	Uranus	Neptune
Atmosphere	H, He, methane, ammonia, sulfides in different proportions			
Magnetic Field	X	X	X	X
Moons	79 - 4 Galilean	80+	27+	14

# Moons of the Solar System- Nearly 200 known!



Charon 1186 km   Umbriel 1169.4 km   Ariel 1158 km   Dione 1118 km   Tethys 1059 km   Earth 12,756.28 km

Diameters of the Terrestrial Bodies  
of the Solar System



# How do we know about these moons?



Voyager 1 & 2  
(launched 1977)



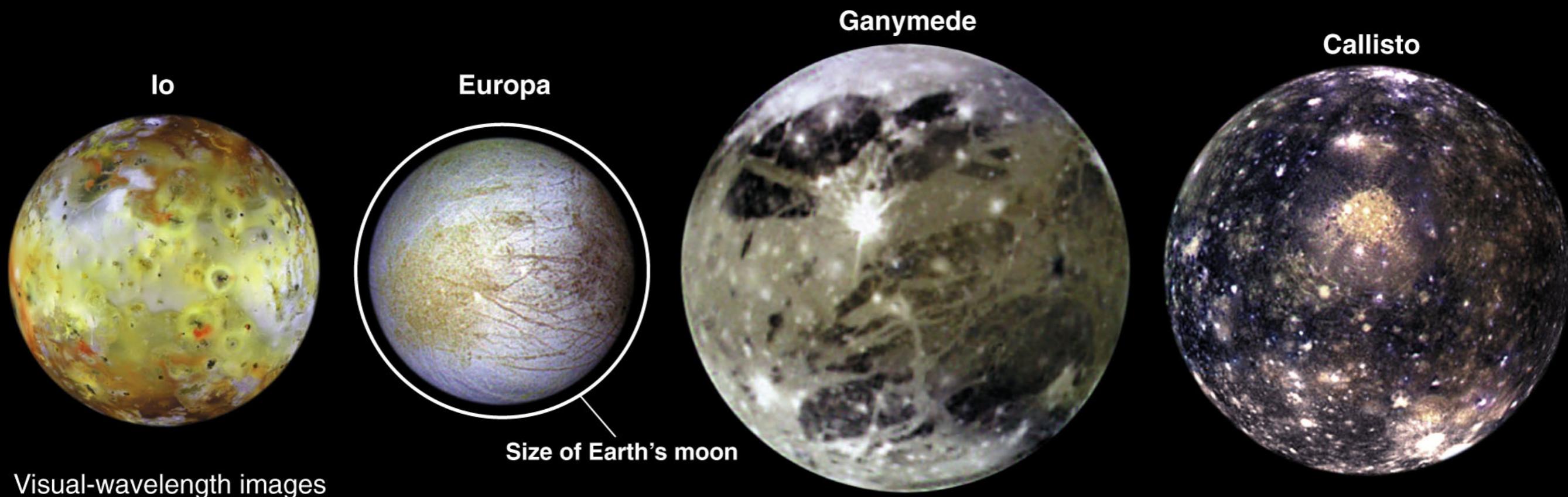
Galileo  
(launched 1989)



Cassini  
(launched 1997)

# Jupiter has four large moons and at least 75 smaller moons.

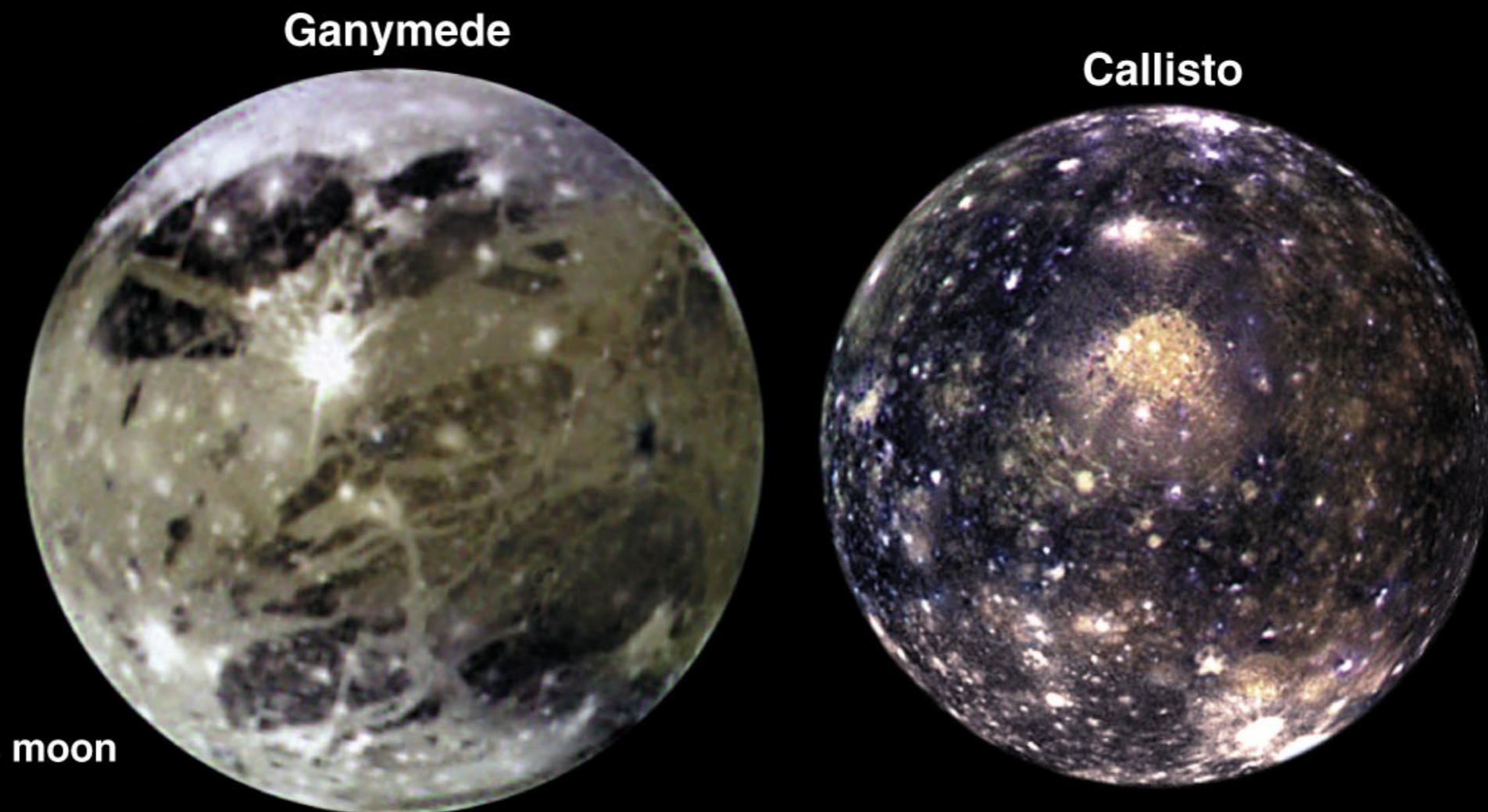
- Larger telescopes and modern techniques are rapidly finding more small moons orbiting the Jovian planets.



- These four were discovered by Galileo in the 1600s.

The outermost Galilean moons, Ganymede and Callisto, are about the size of Mercury—one and a half times the size of Earth's moon.

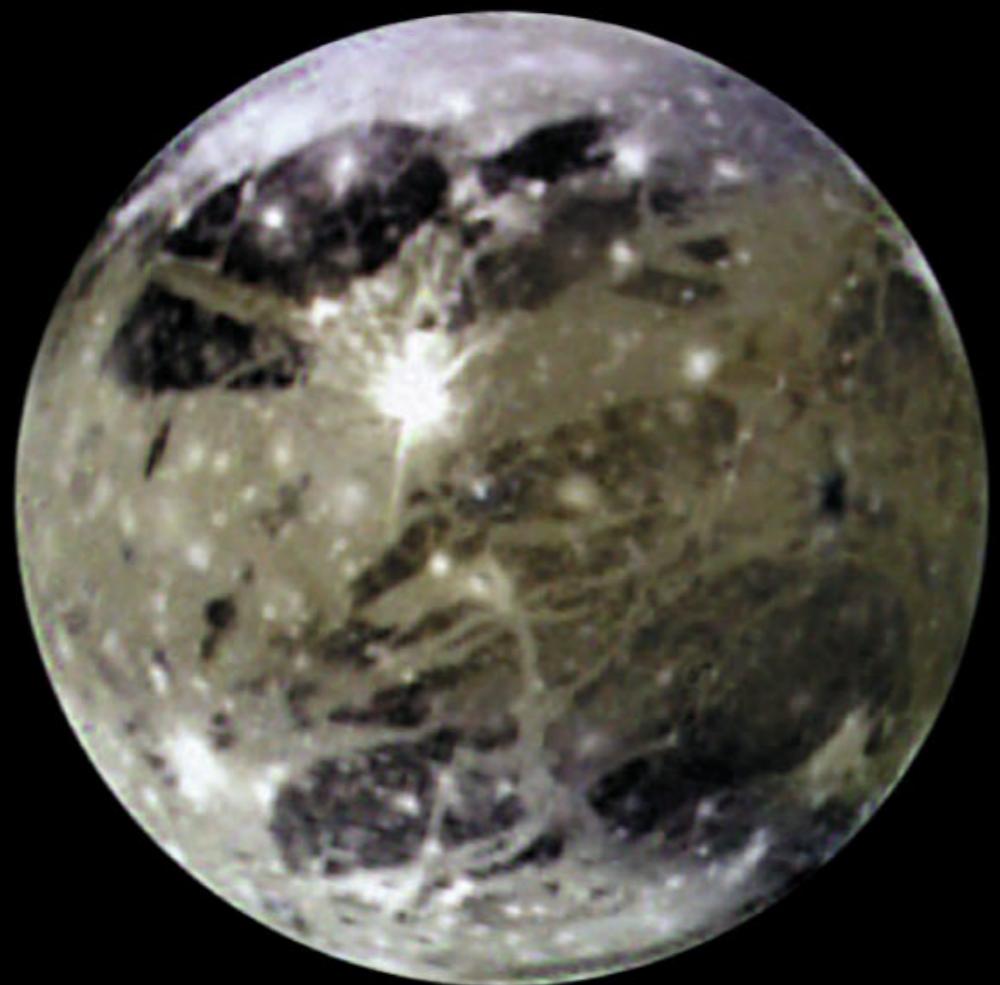
Ganymede is the largest moon in the solar system.



They have low densities—only 1.9 and 1.8 g/cm<sup>3</sup> respectively.

- This must mean that they consist roughly of half rock and half ice.

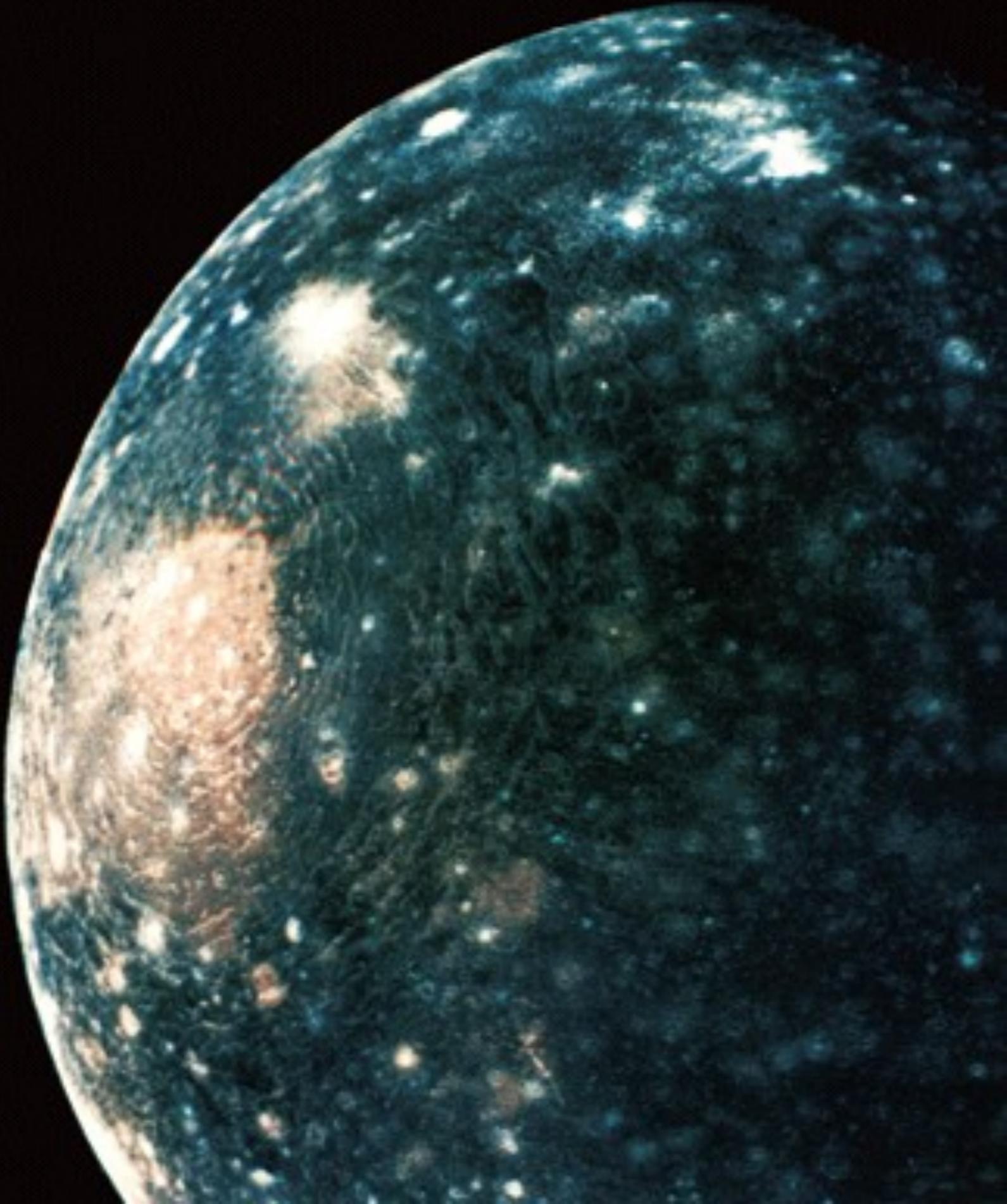
Ganymede



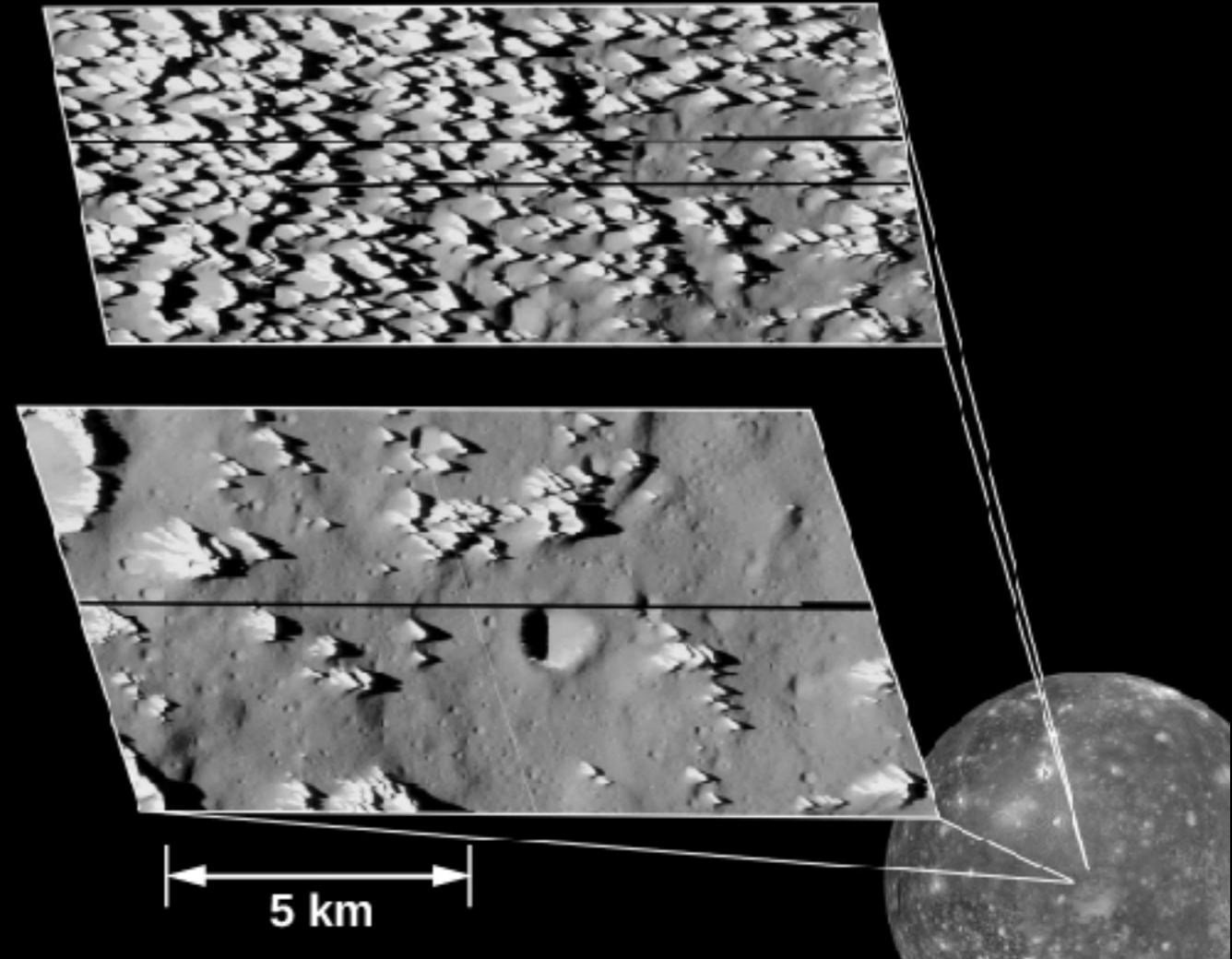
Callisto



Callisto wears  
the scars of a  
huge asteroid  
impact

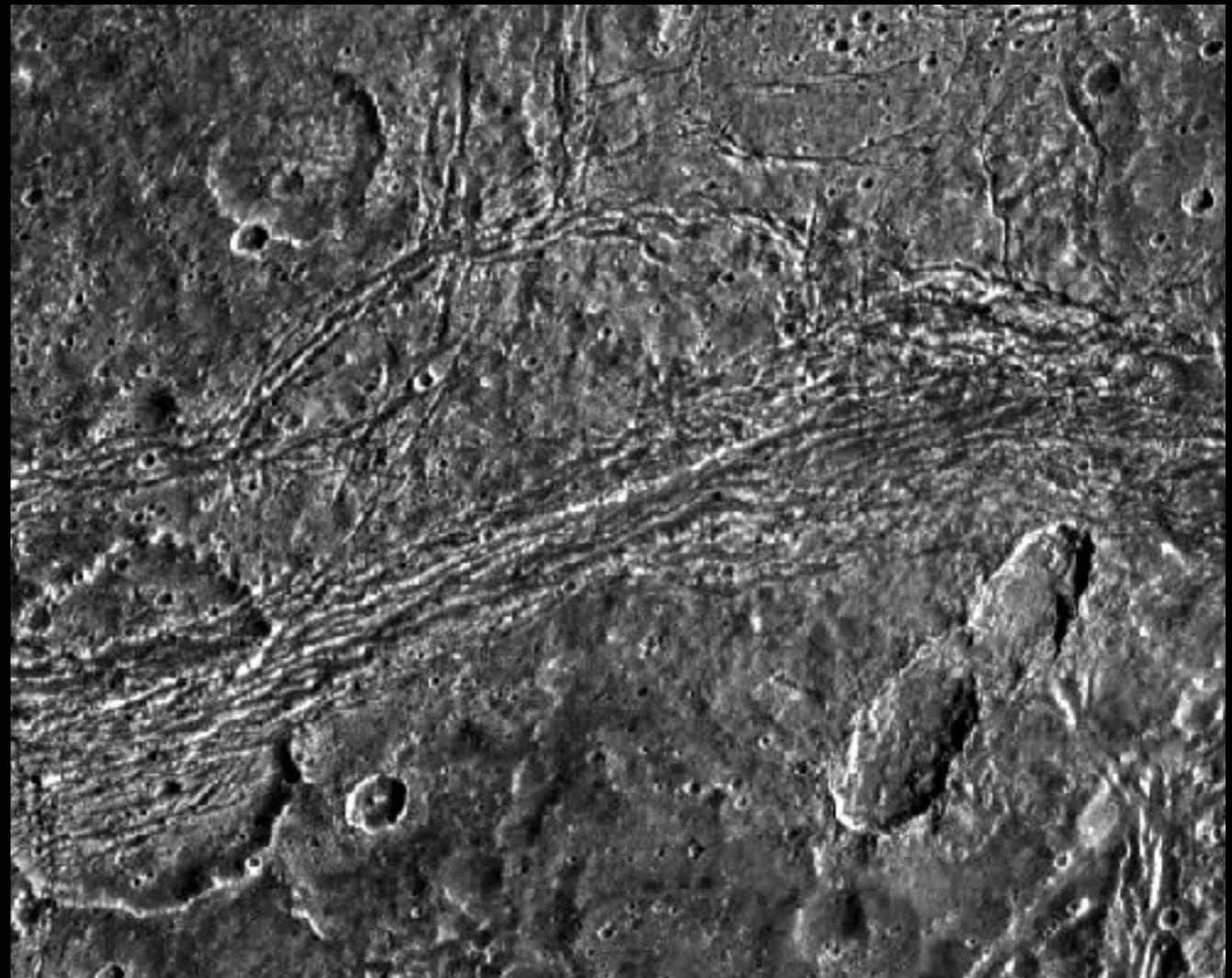


Callisto is quite cold (-140C).  
Its surface is a combination of craters and ice spires



The ice is essentially rock solid. Spires (80-100m tall) erode gradually, and dust slides down them.

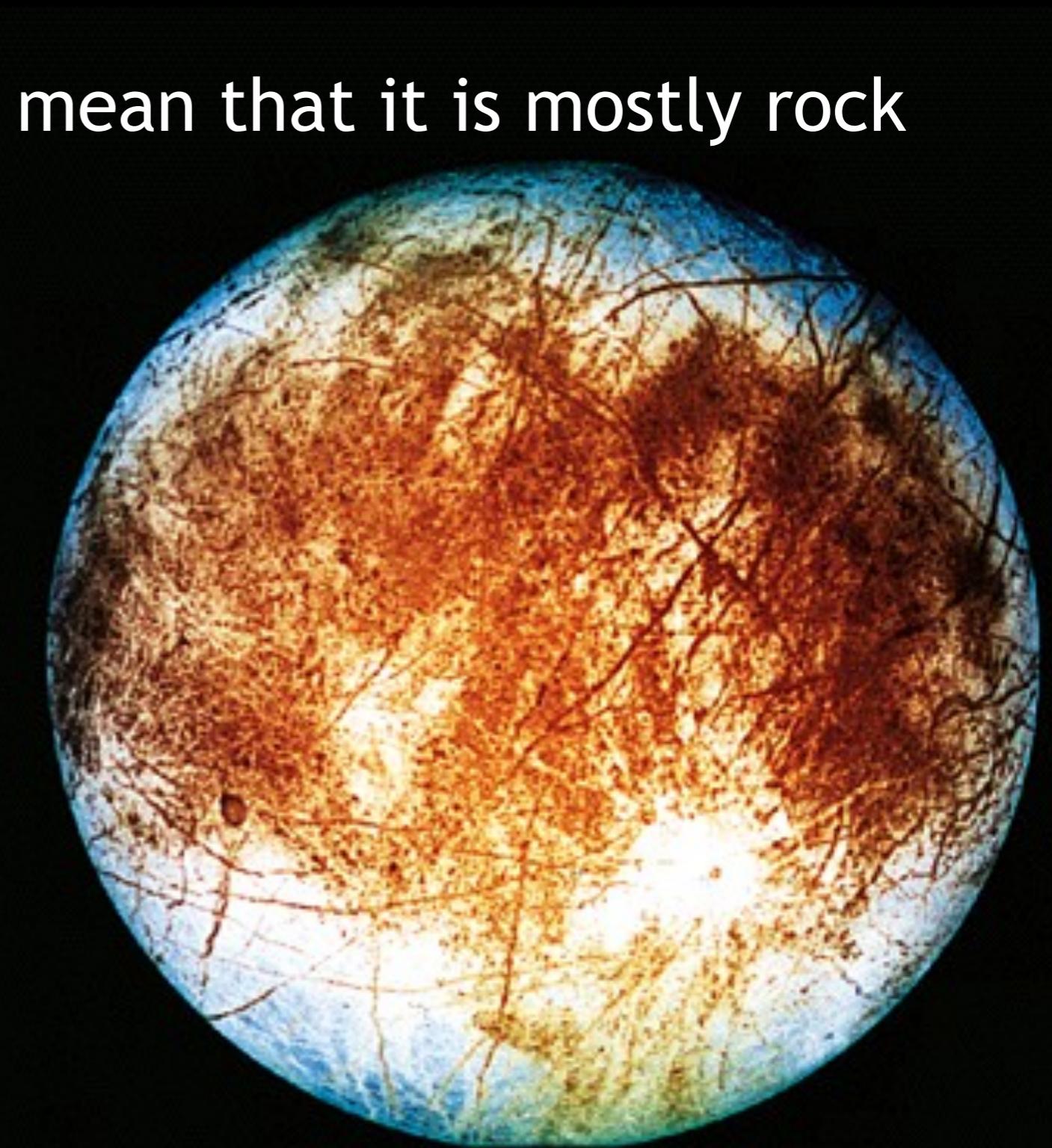
Ganymede is huge! -140C).  
Its surface craters (~25%) and cracks/ridges.



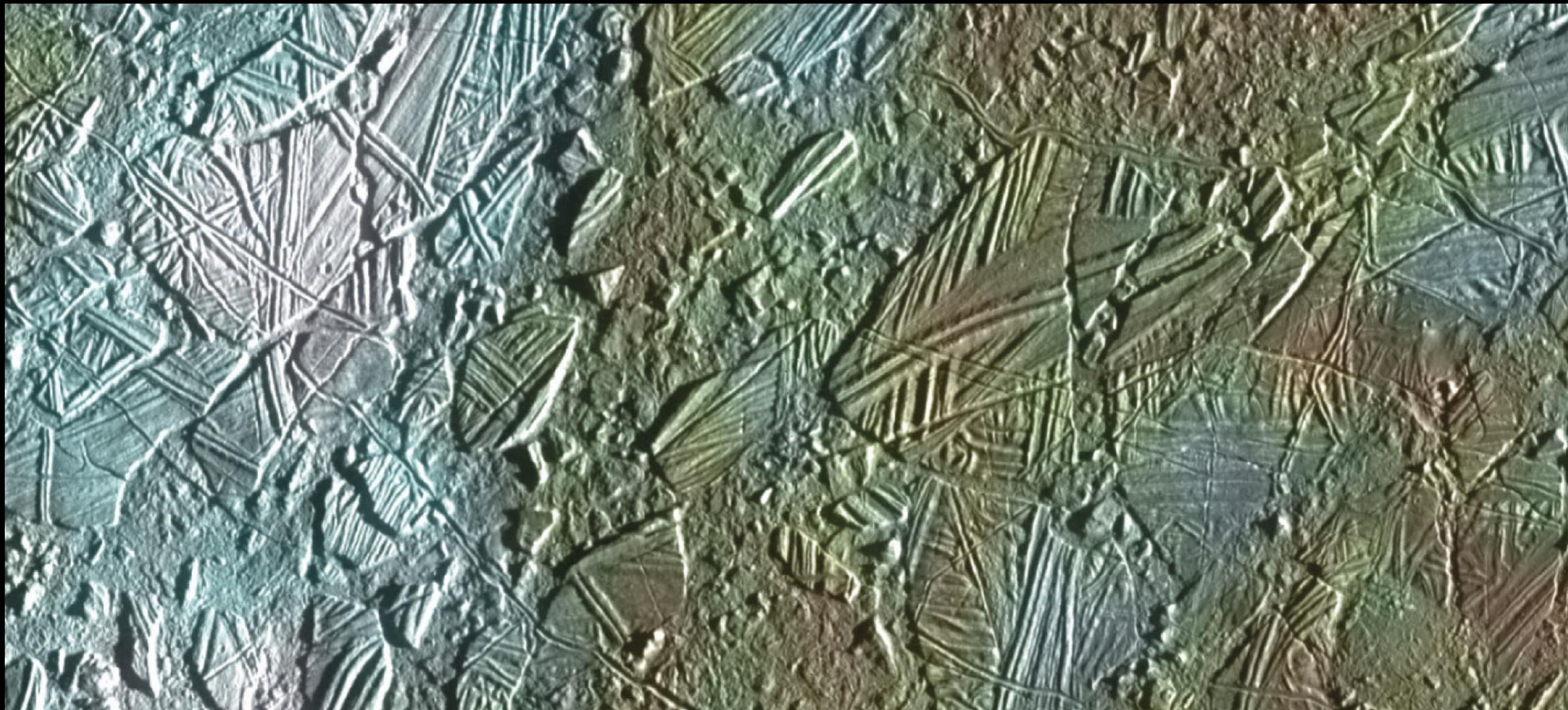
The lines and grooves on this planet were formed by tectonic forces. The gravity of Jupiter is tugging on Ganymede and causing it to flex and crack.

The density of the next moon inward,  
Europa, is  $3 \text{ g/cm}^3$ .

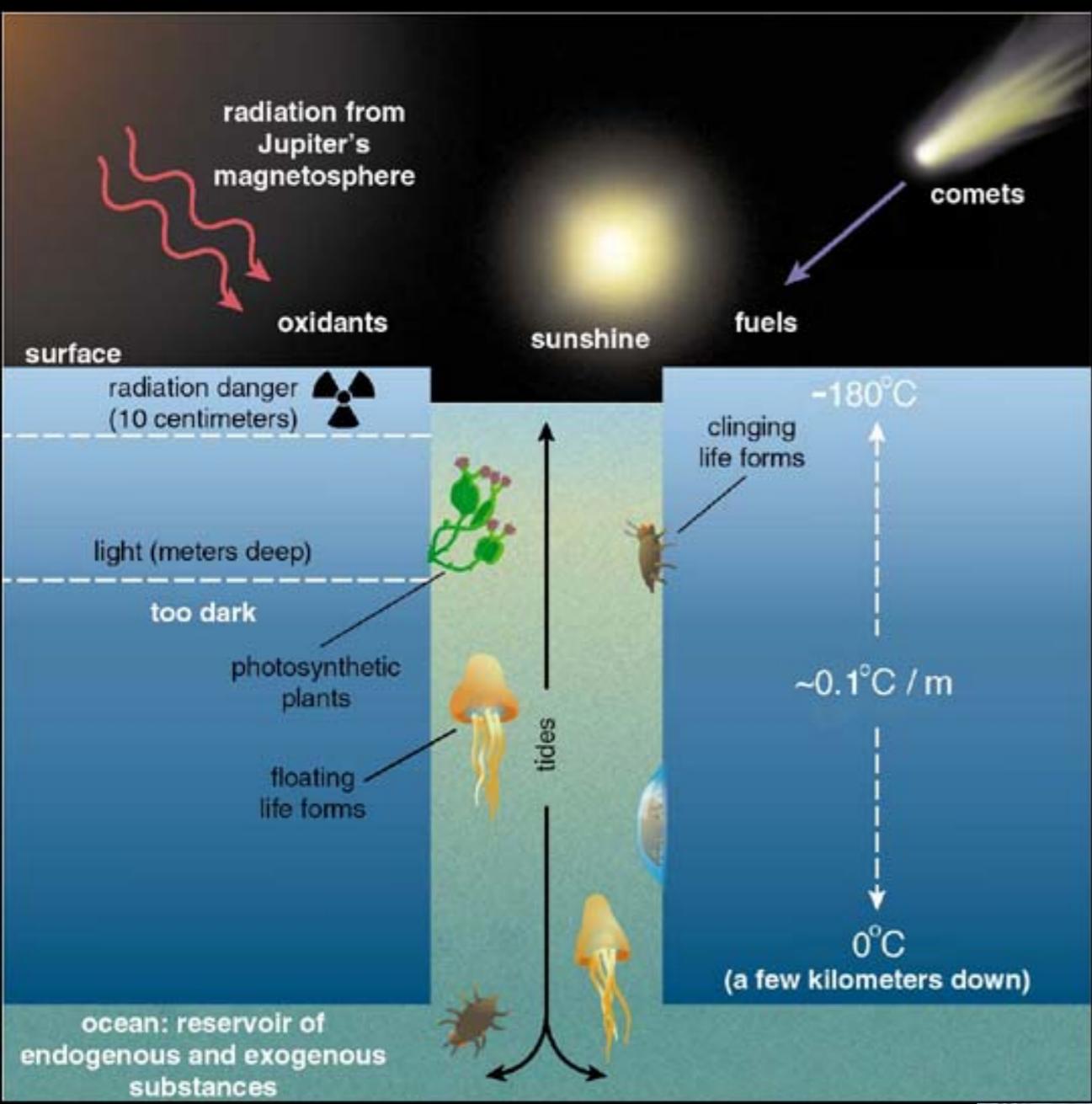
- This is high enough to mean that it is mostly rock with a thin icy crust.



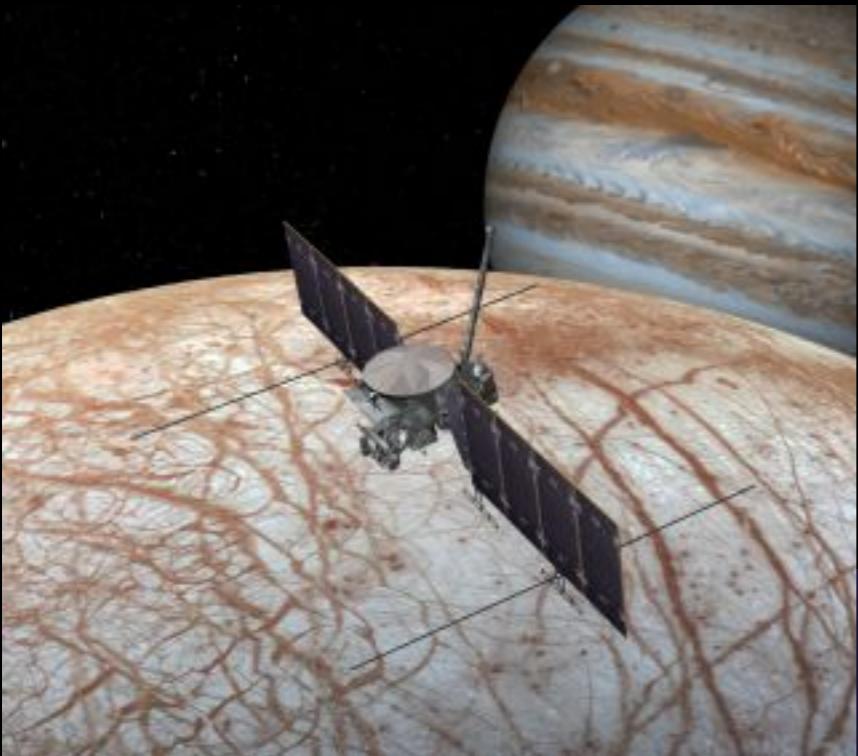
- Europa's visible surface:
  - Is very clean ice
  - Contains very few craters - young surface
  - Has long cracks in the icy crust
  - Has complicated terrain that resembles blocks of ice in Earth's Arctic Ocean



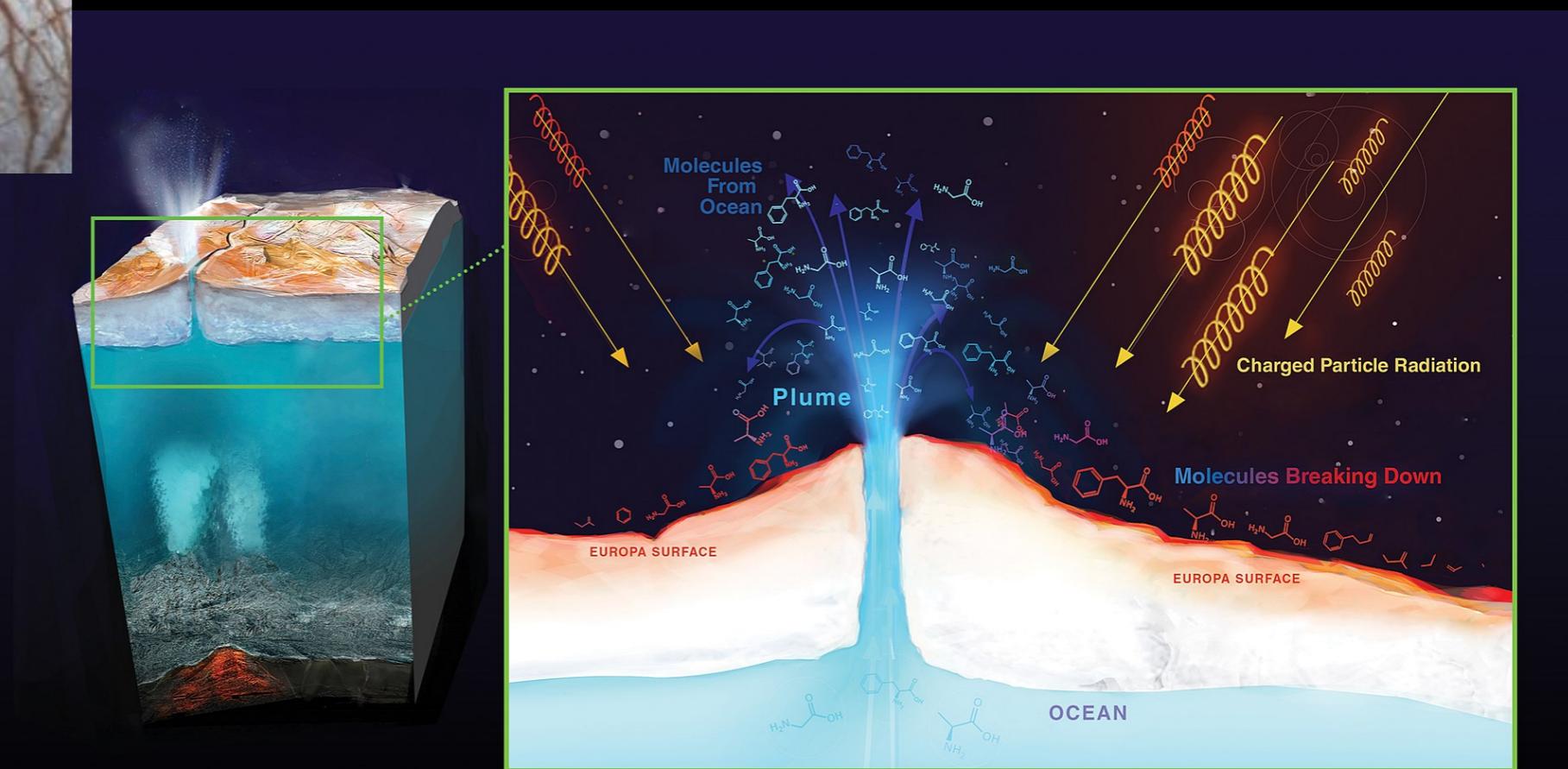
Europa's gravitational influence on the Galileo spacecraft reveals that a liquid-water ocean perhaps 200-km deep lies below the 10- to 100-km-thick crust.



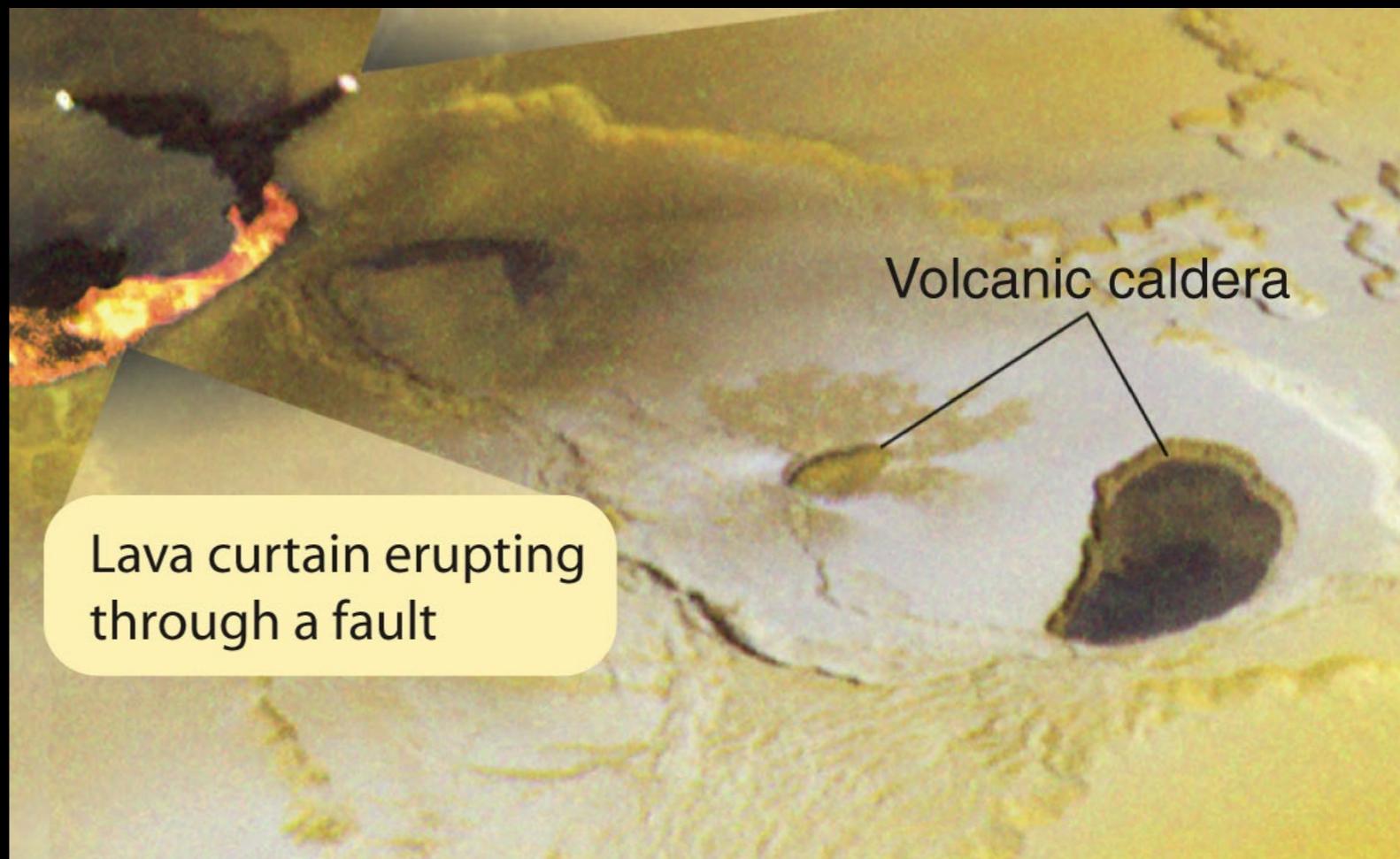
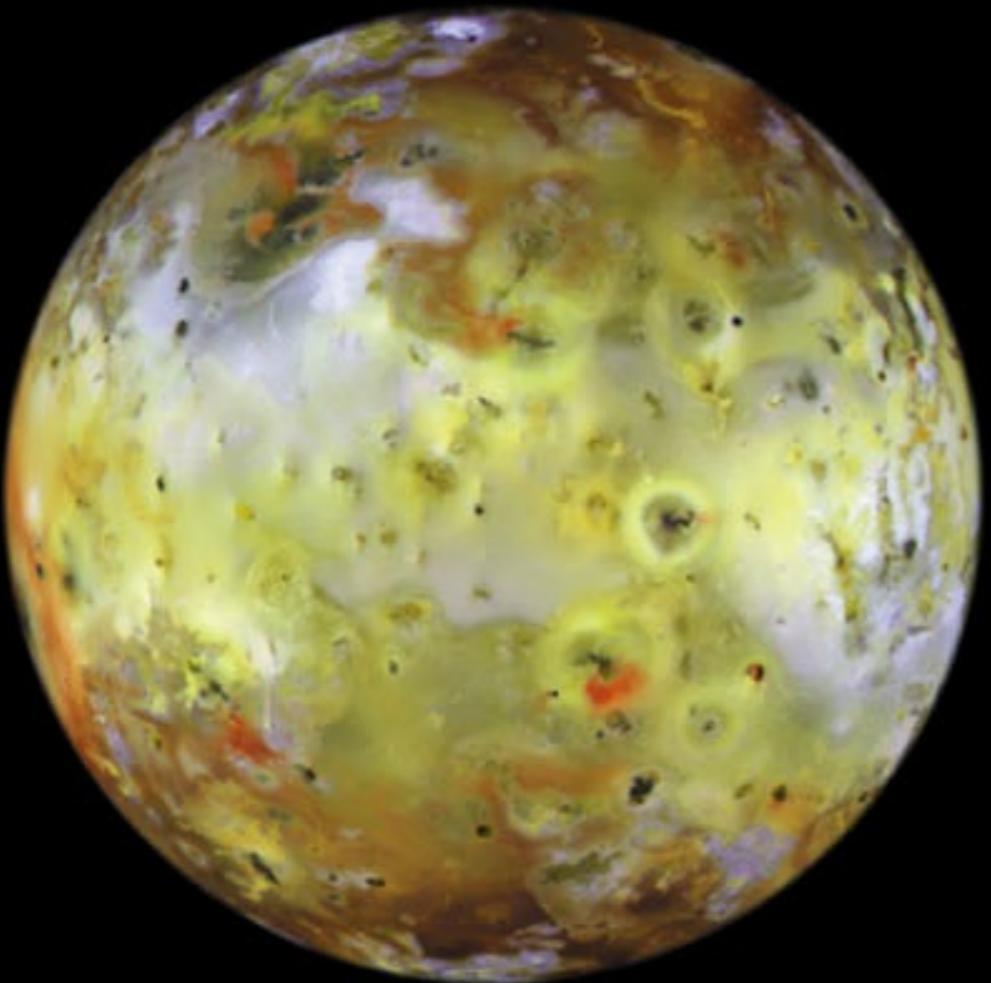
# How could we detect Europa's potential ocean?



Europa Clipper mission-  
set for launch in 2024

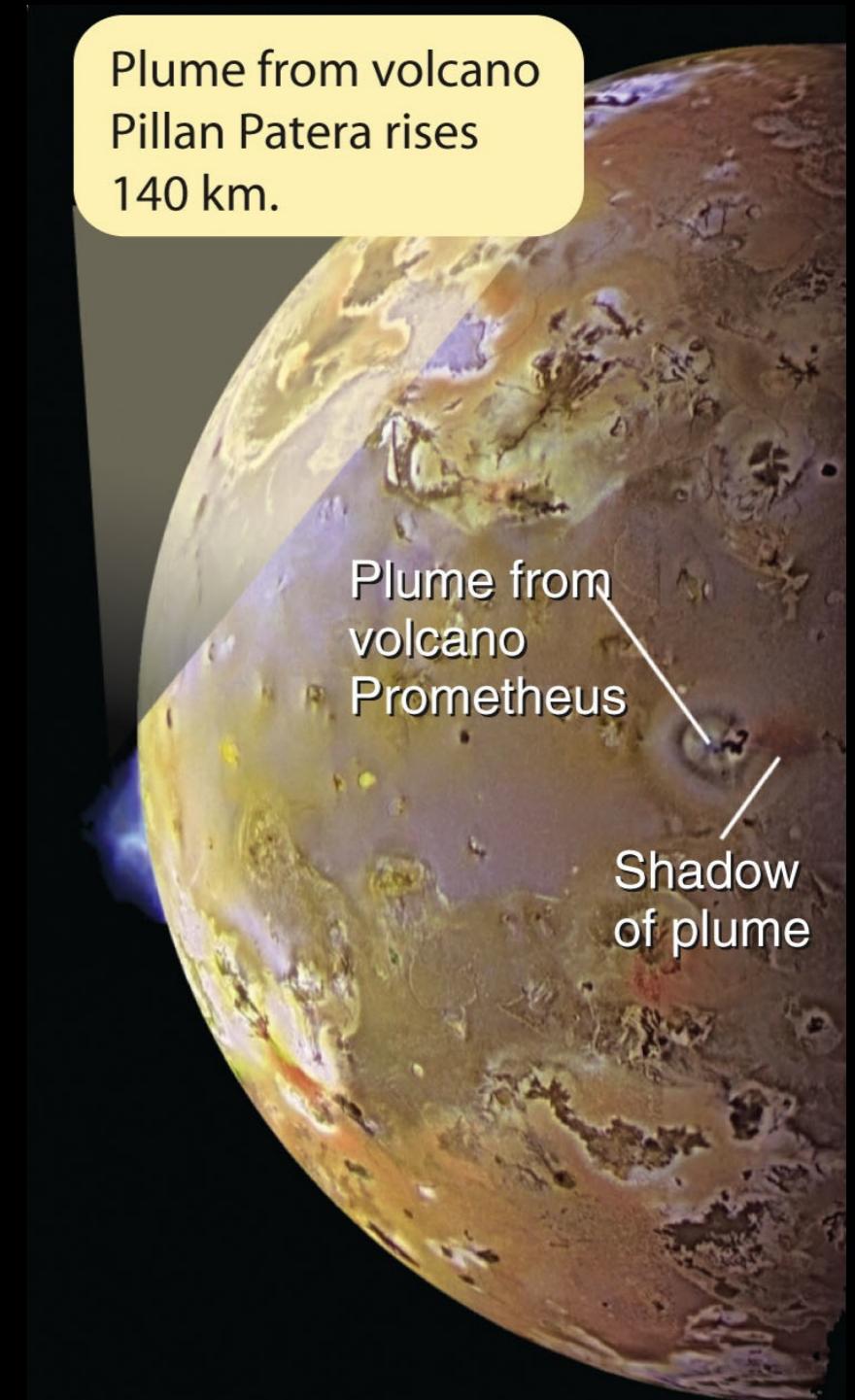
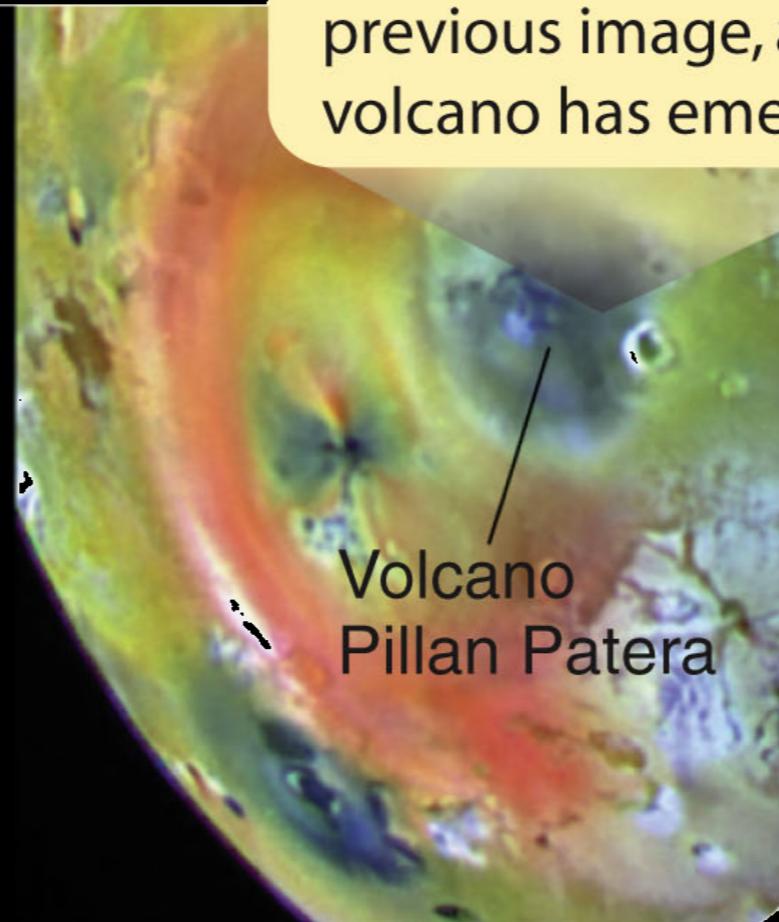
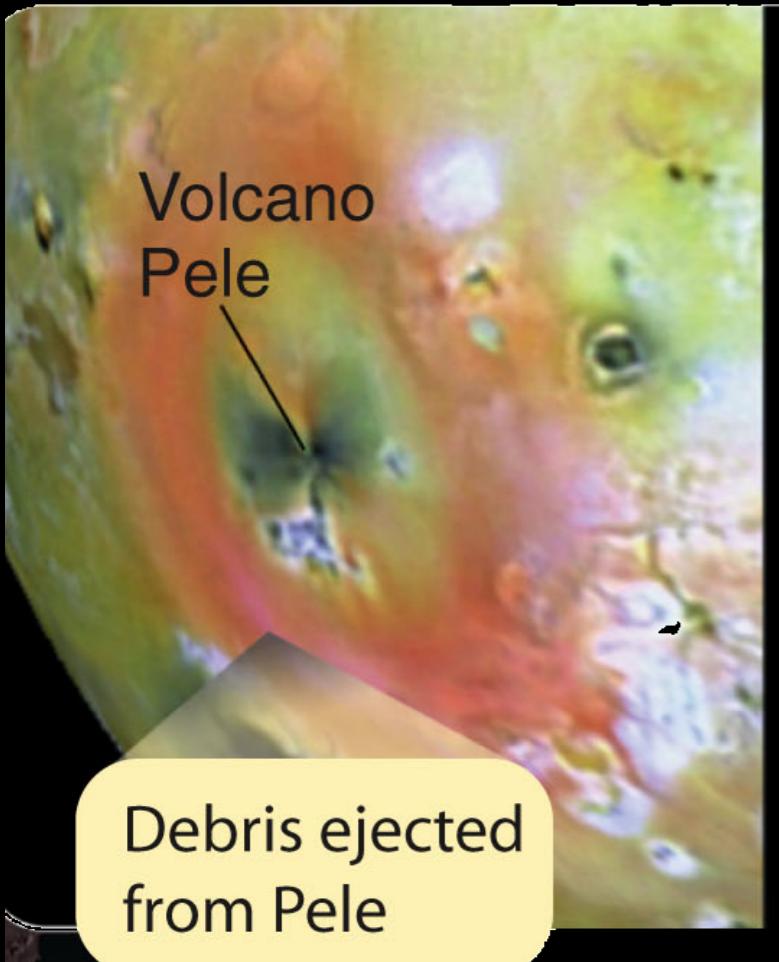


Images from spacecraft reveal that Io, the innermost of the Galilean moons, has over 100 volcanic vents on its surface.

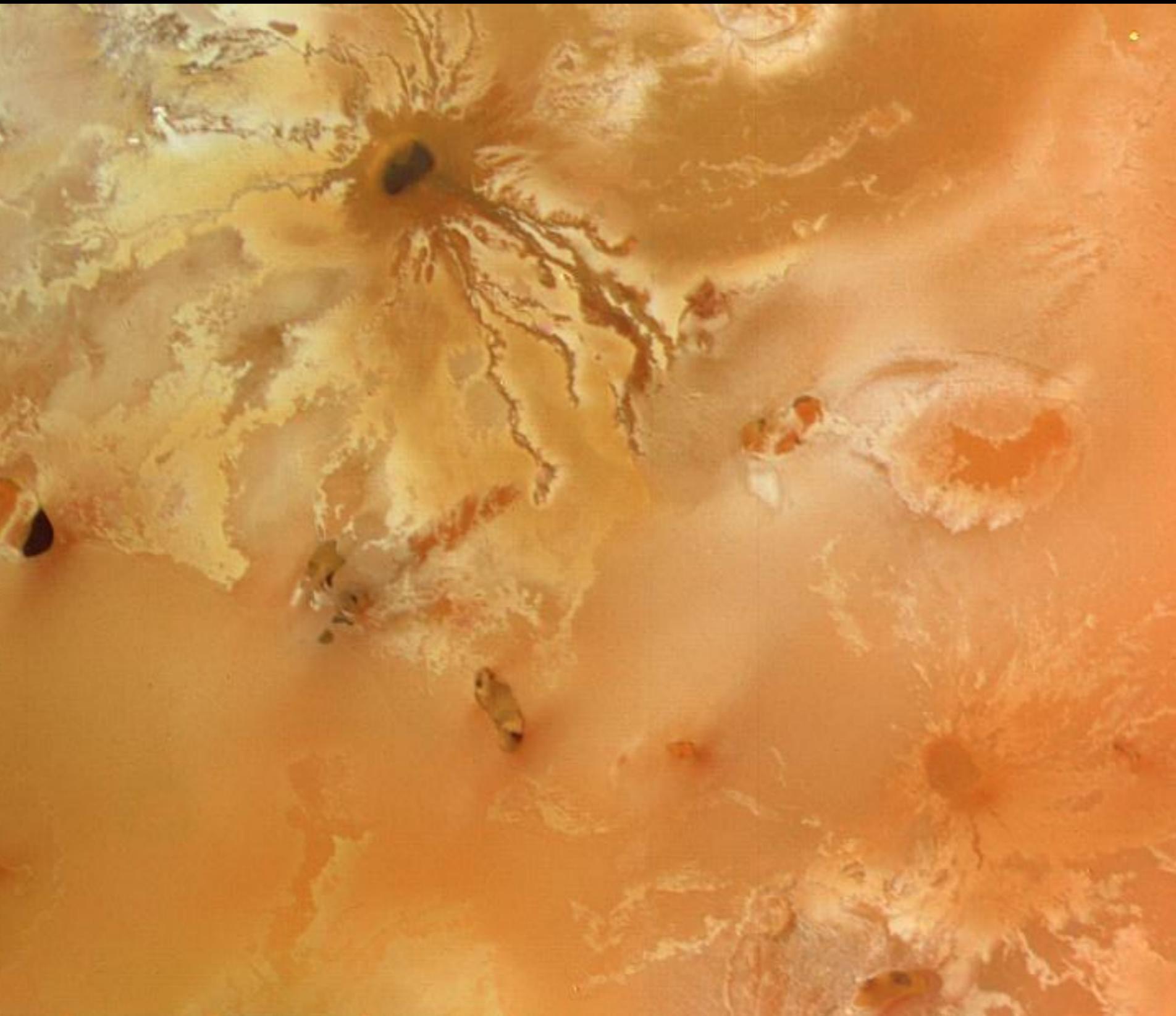


# The active volcanoes throw sulfur-rich gas and ash high above the surface.

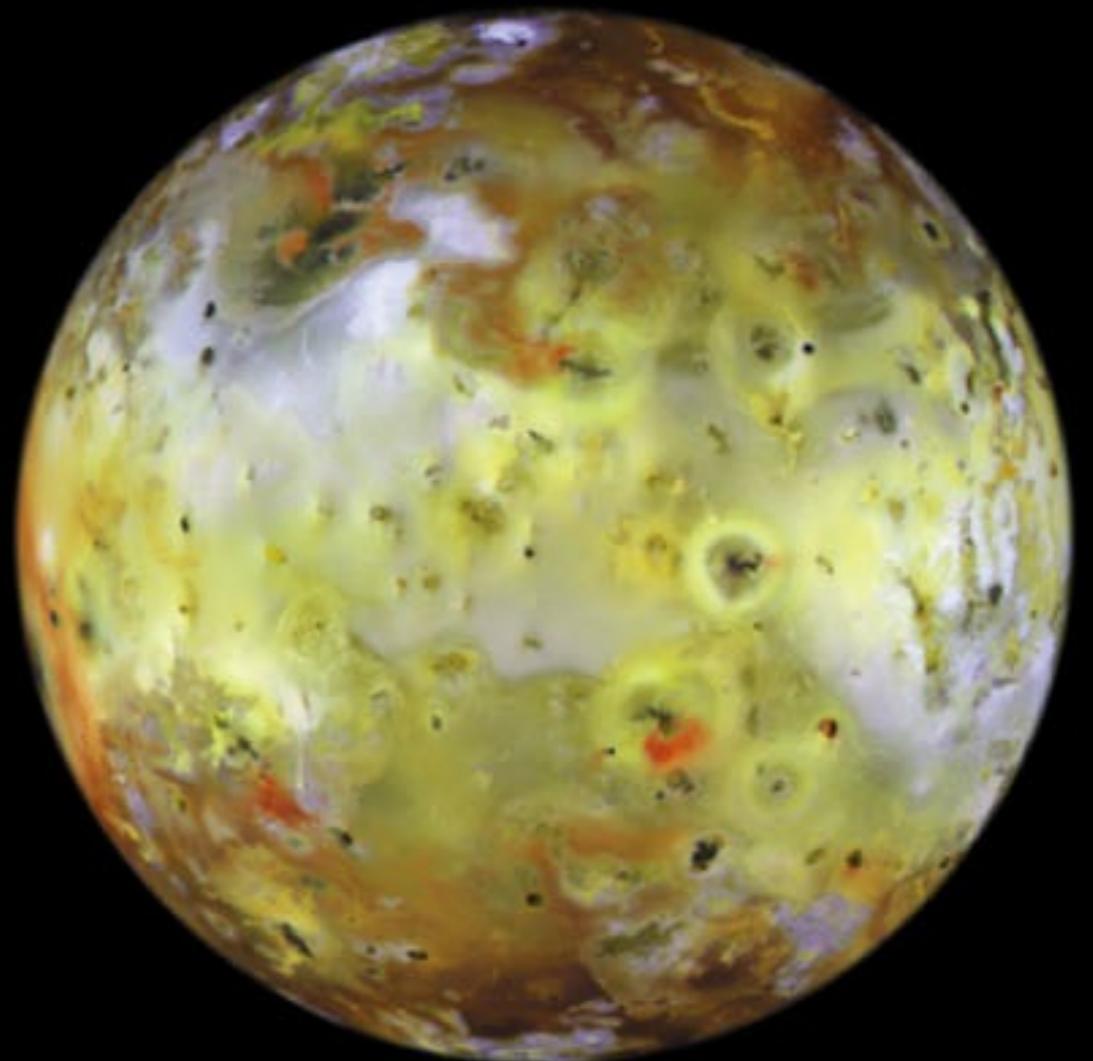
- The ash falls back to bury the surface at a rate of a few millimeters a year.



- Io's density is  $3.6 \text{ g/cm}^3$ .
- Thus, it is not ice but rather rock and metal.



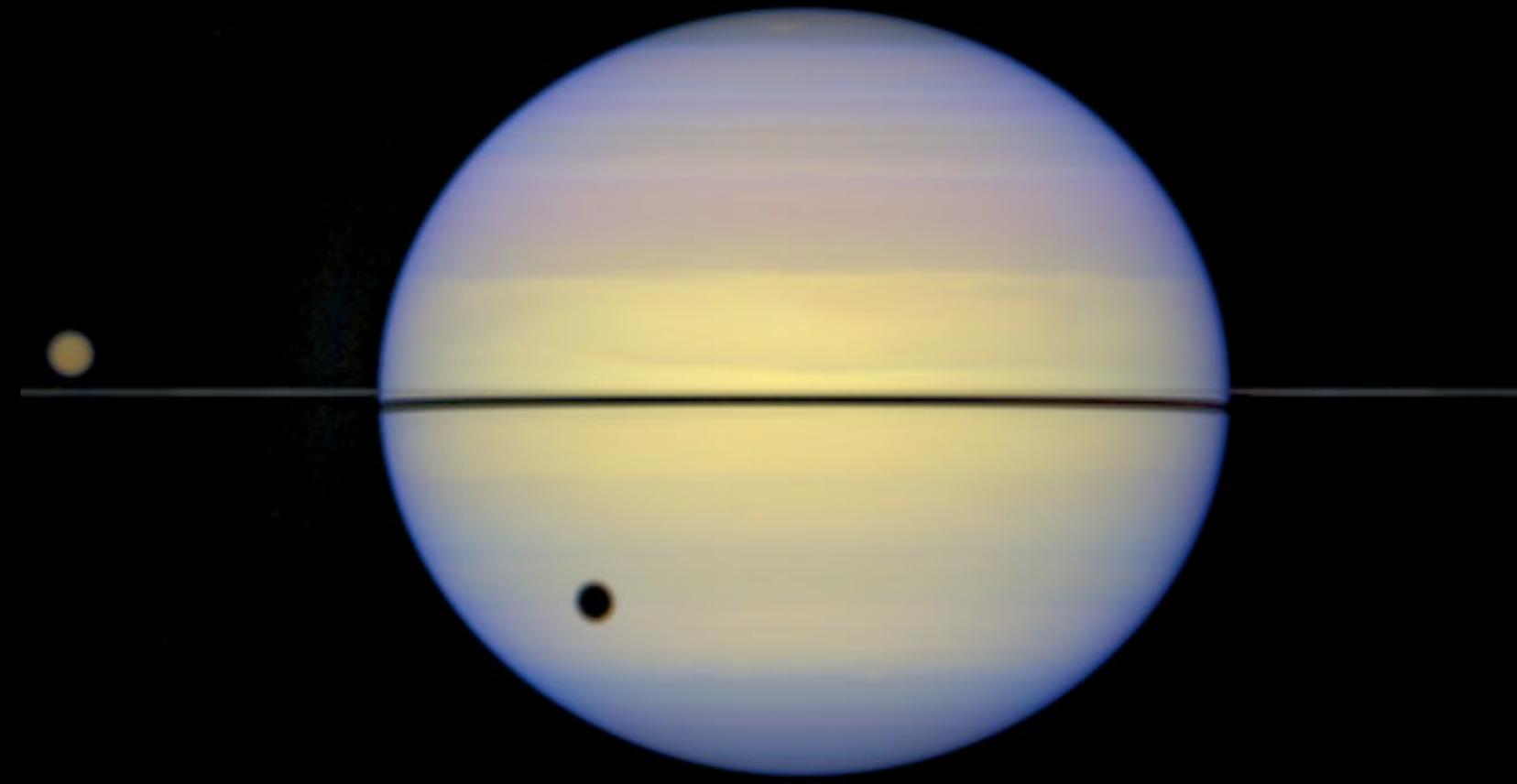
- Io's volcanism seems to be driven by **tidal heating**
  - Io follows a slightly **elliptical** orbit—caused by its interactions with the other moons.
  - The resulting friction heats its interior.
  - That heat flowing outward causes the volcanism.
  - There are more than 100 active volcanoes seen on Io.

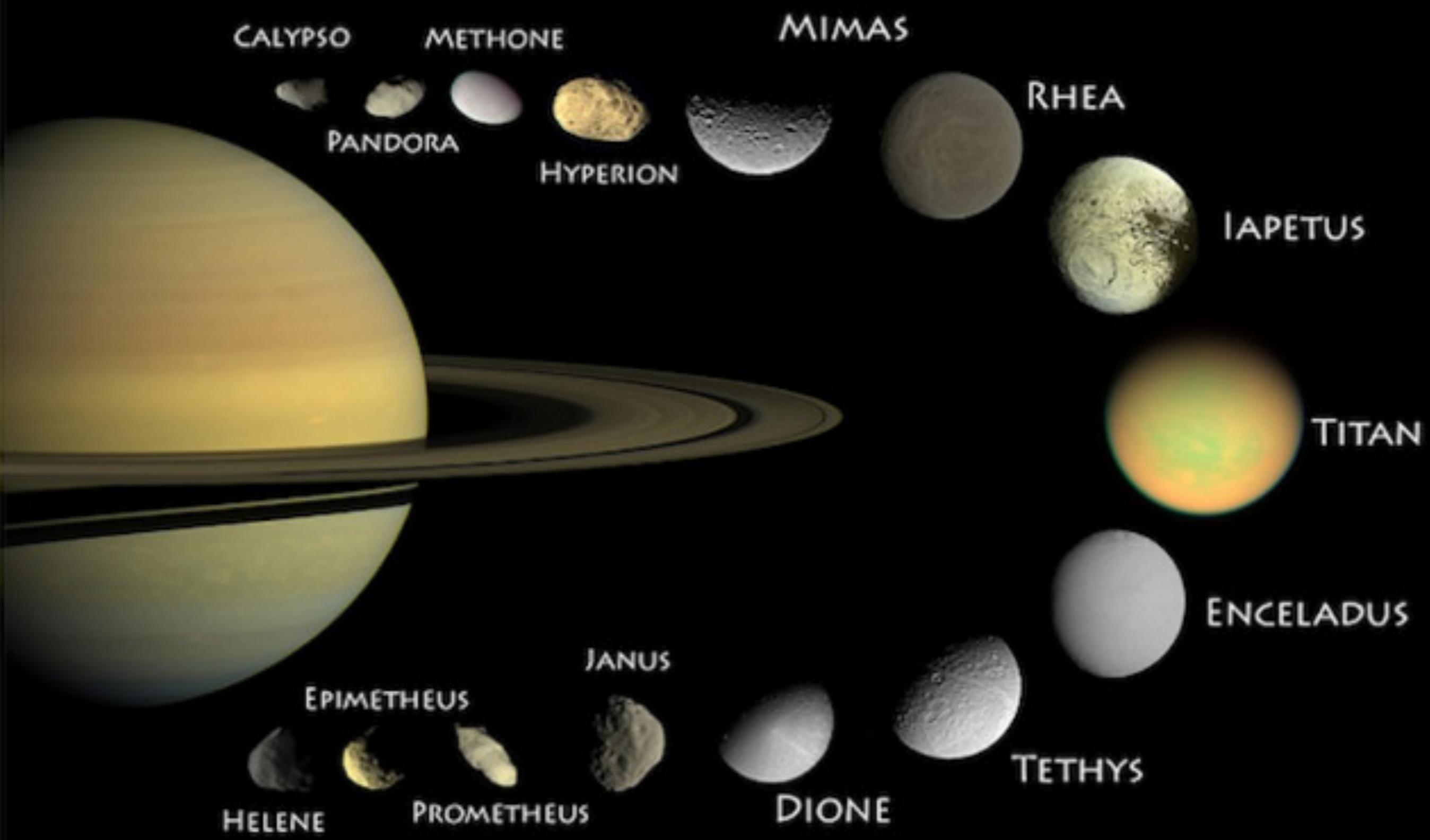


What about Saturn's moons?

The ring particles are confined in a thin plane spread among small moons and confined by gravitational interactions with larger moons.

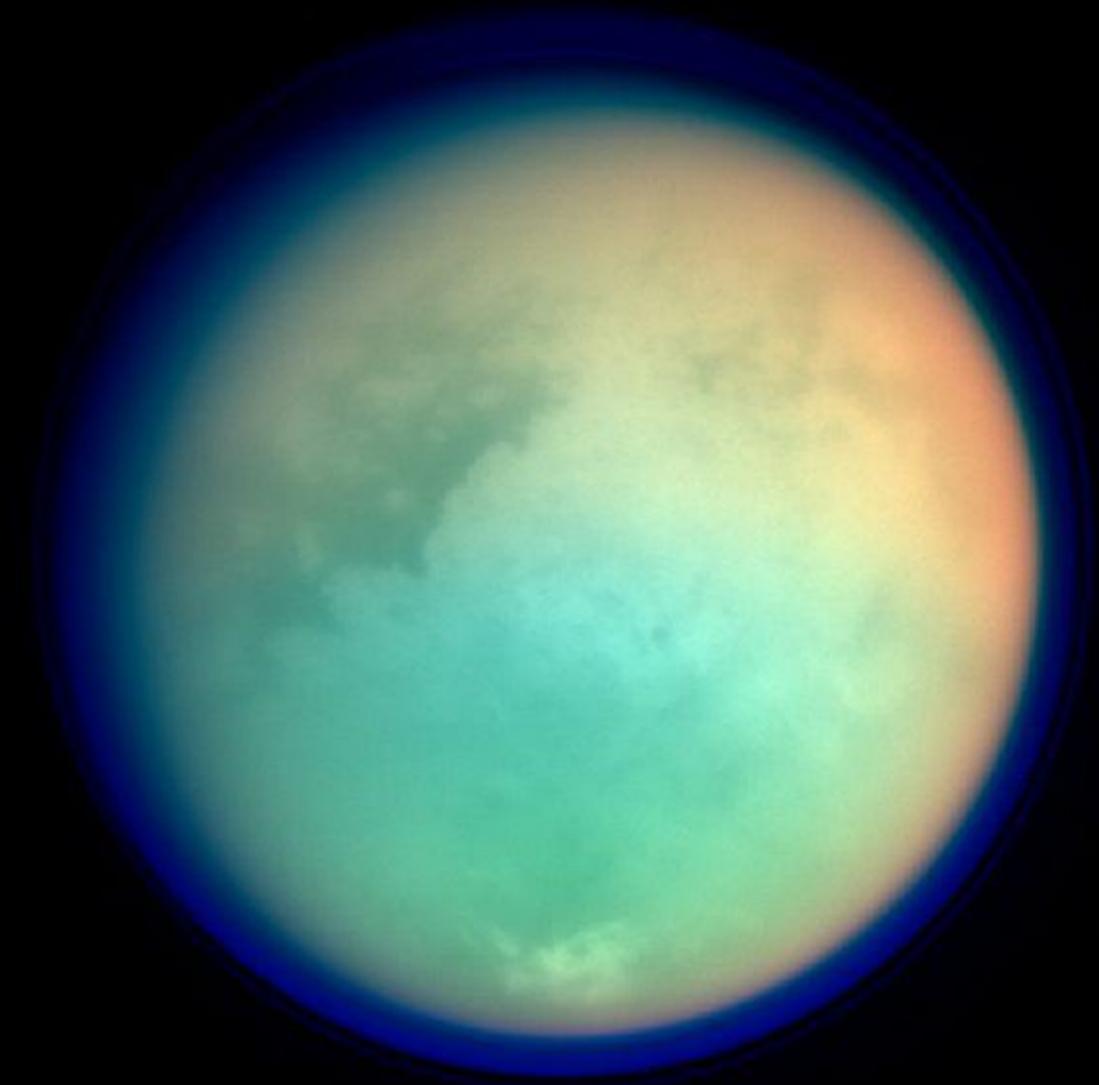
Without the moons,  
there would be no  
rings.



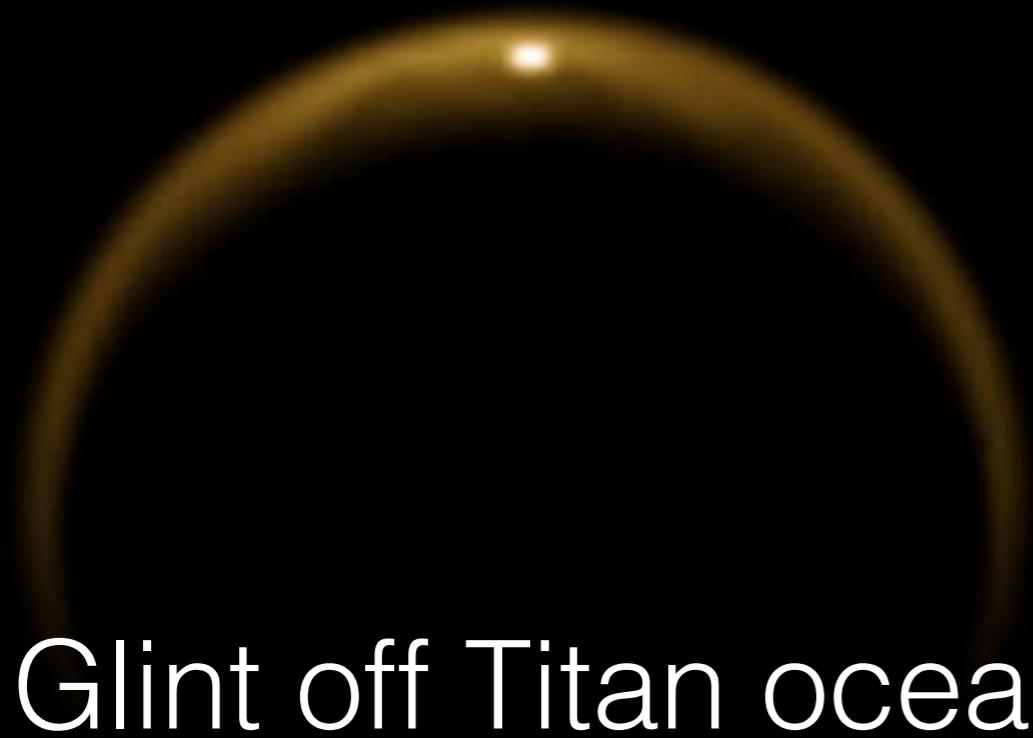


- The largest of Saturn's 80+ moons is Titan.
- Titan is so cold that its gas molecules do not travel fast enough to escape.

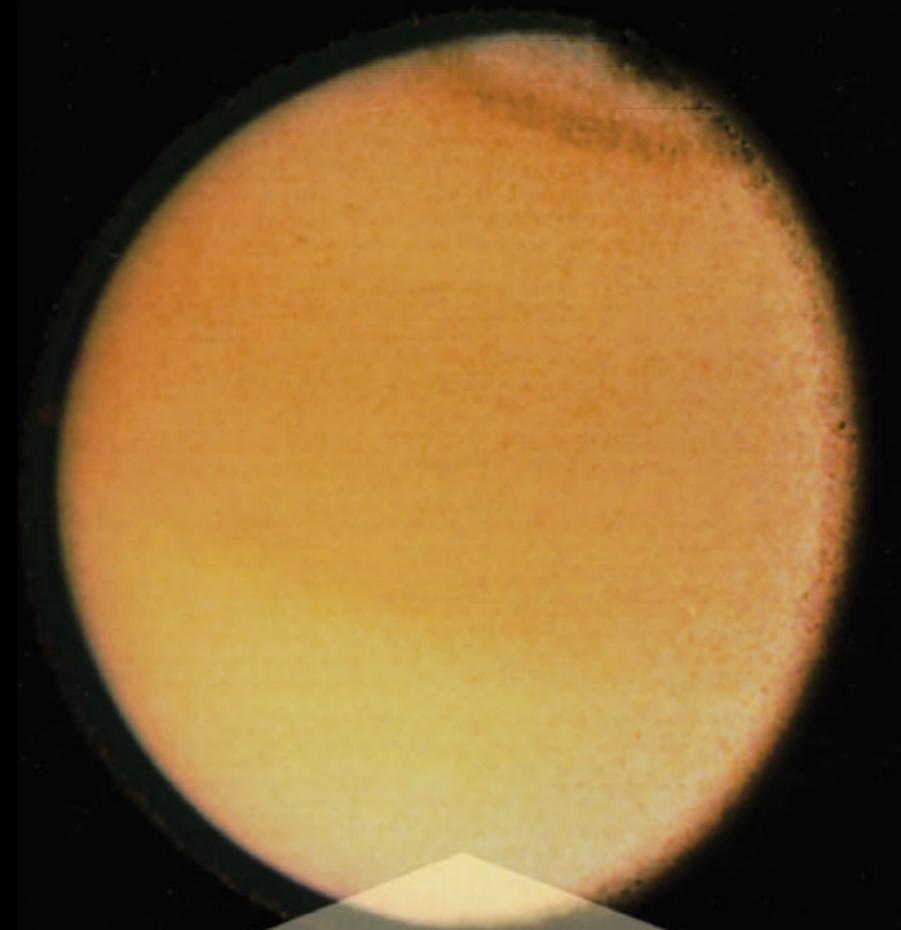
- It has an **atmosphere** composed mostly of nitrogen, with traces of argon and methane.



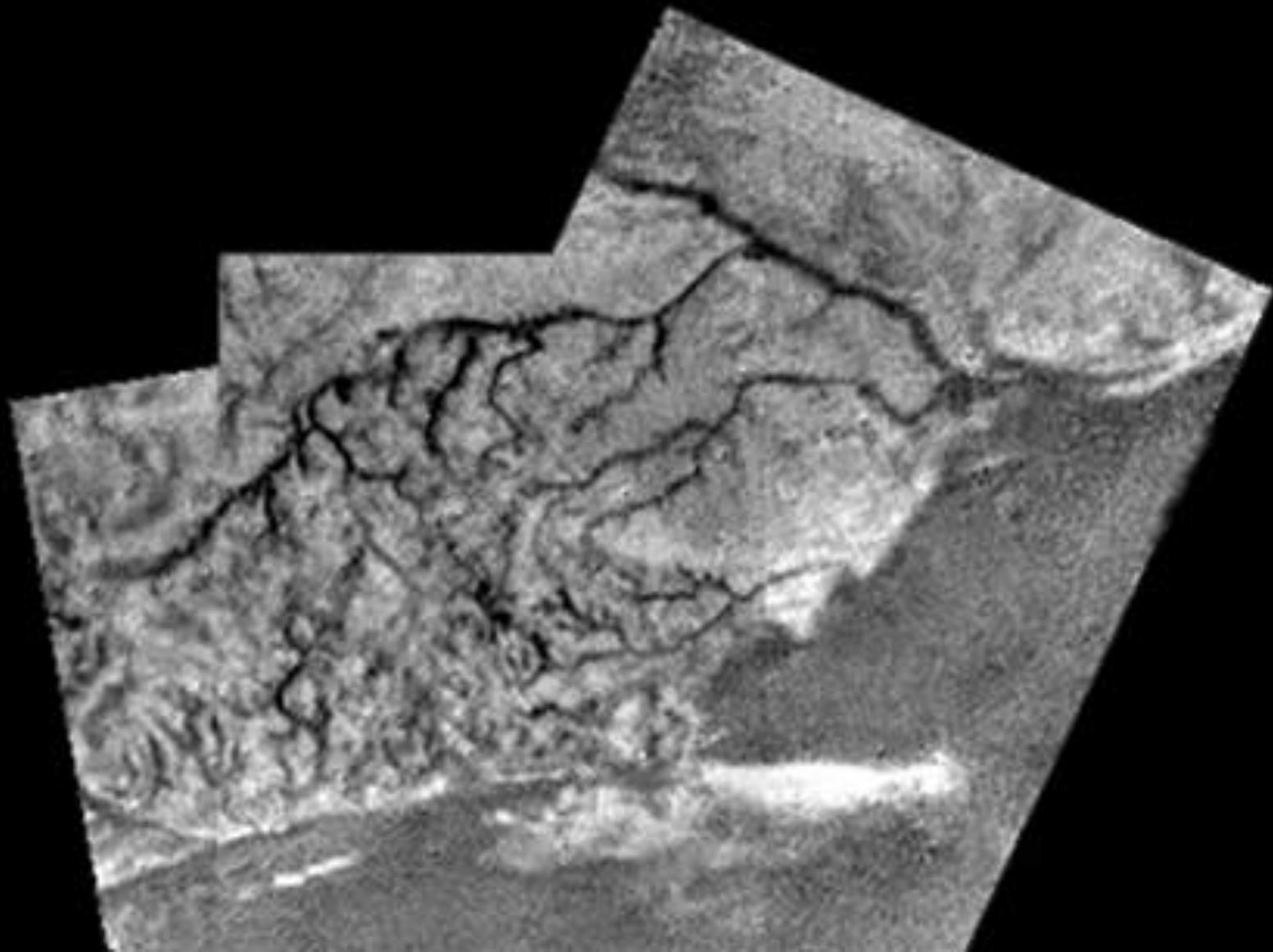
Titan's surface is mainly composed of ices of water and methane at  $-180^{\circ}\text{C}$  ( $-290^{\circ}\text{F}$ ).



Glint off Titan ocean



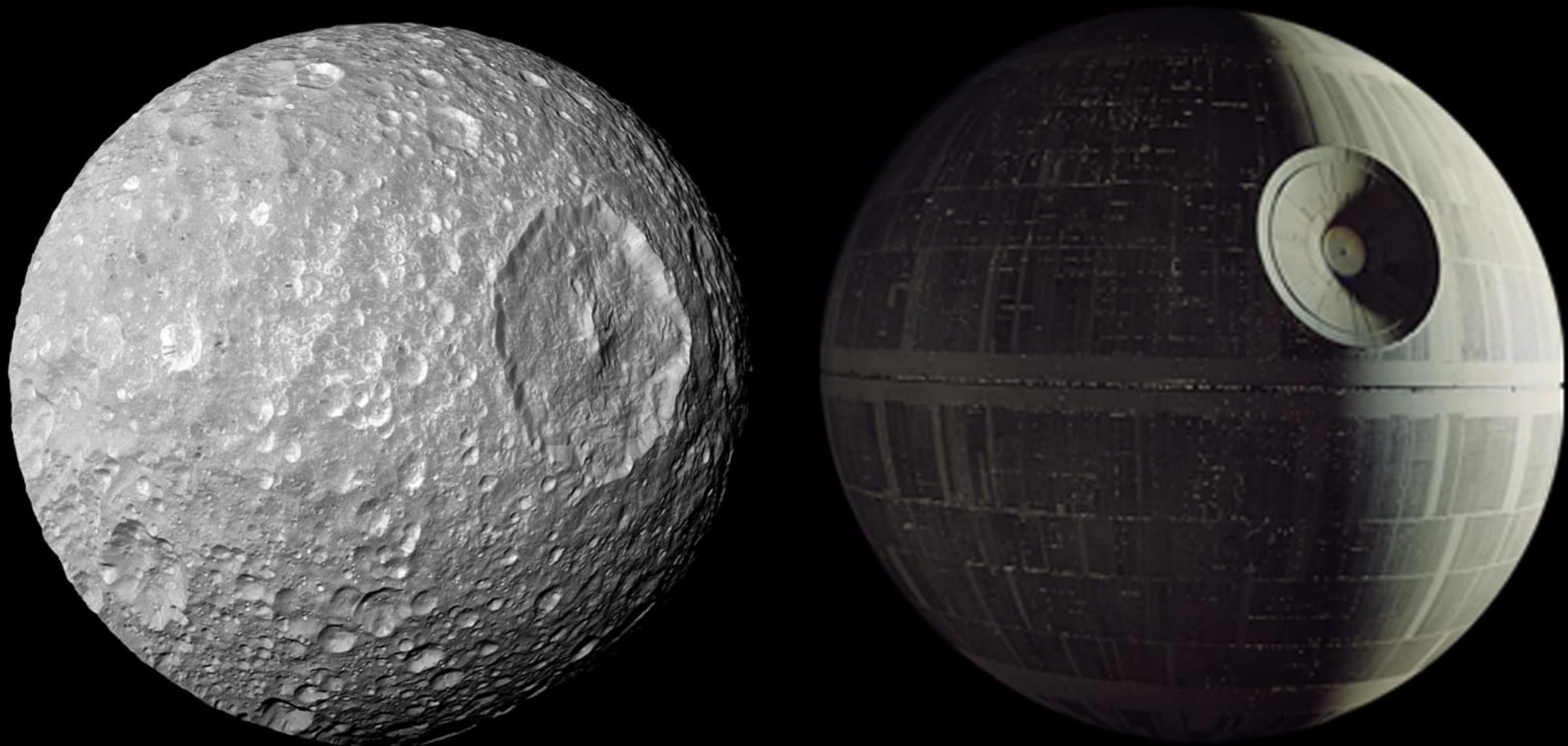
- The Cassini spacecraft dropped the Huygens probe into Titan's atmosphere.
  - It photographed dark drainage channels.
  - This suggests that **liquid methane falls as rain**, washes the dark goo off of the higher terrain, and drains into the lowlands.



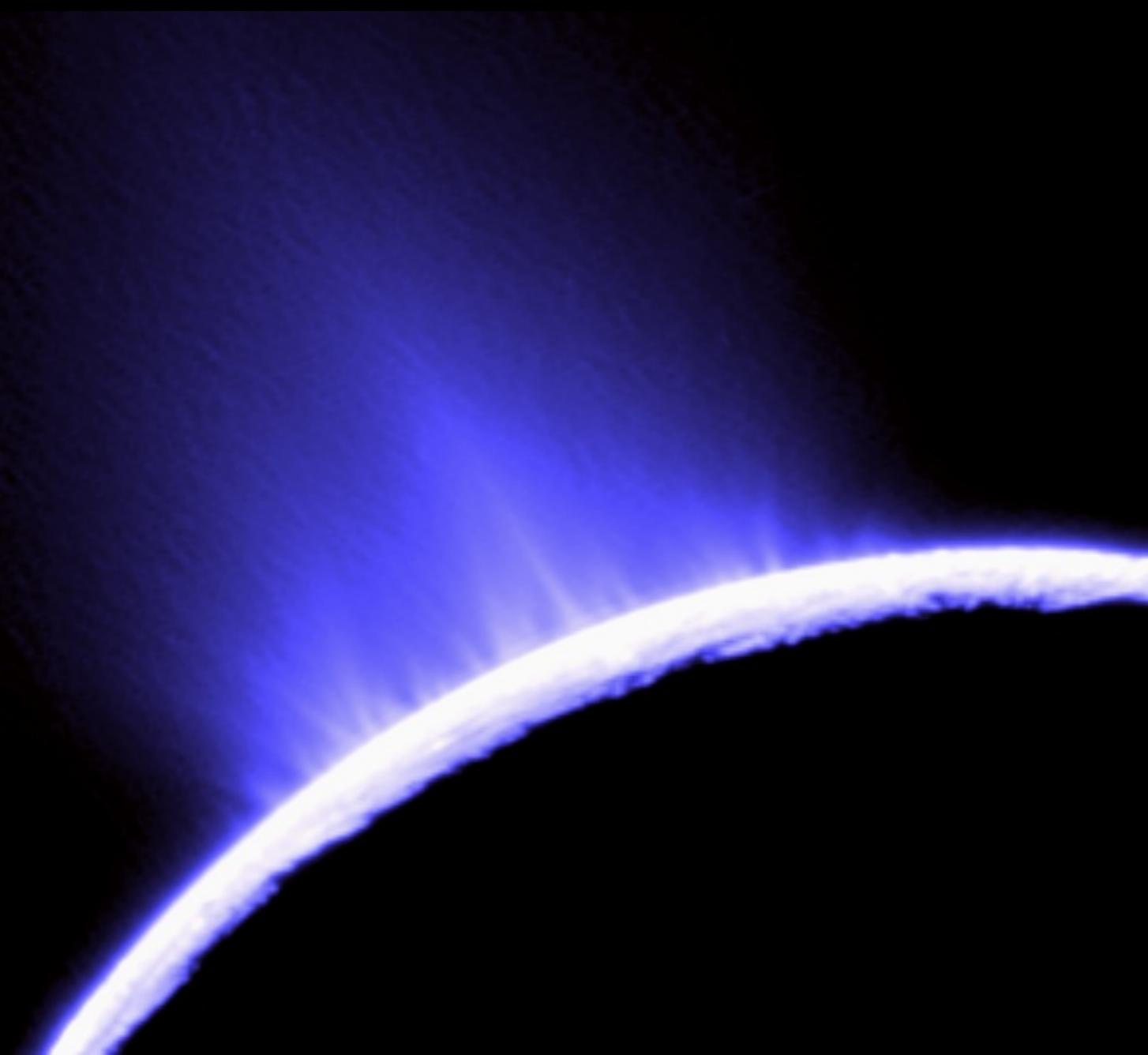
Saturn's moon Mimas...  
Does this look like anything familiar??



- Mimas is famous for being ripped off by George Lucas of Star Wars ...



- Enceladus shows signs of recent geological activity.
- Infrared observations show that its south polar region is unusually warm and venting water and ice geysers.



- Until recently, astronomers could see only five moons orbiting Uranus.
  - However, Voyager 2 discovered 10 small moons in 1986.
  - More have been found in images recorded by new, giant telescopes on Earth.

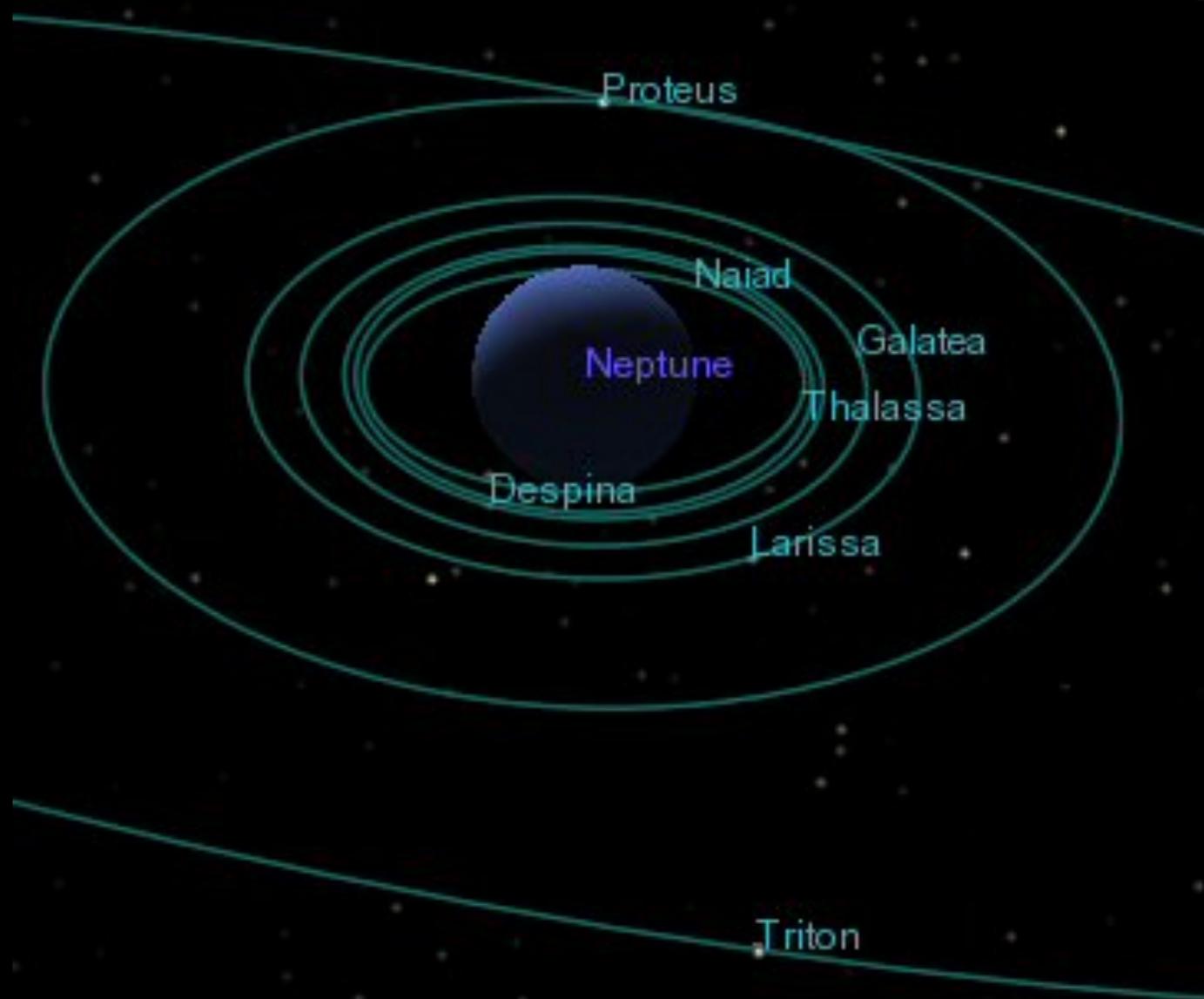


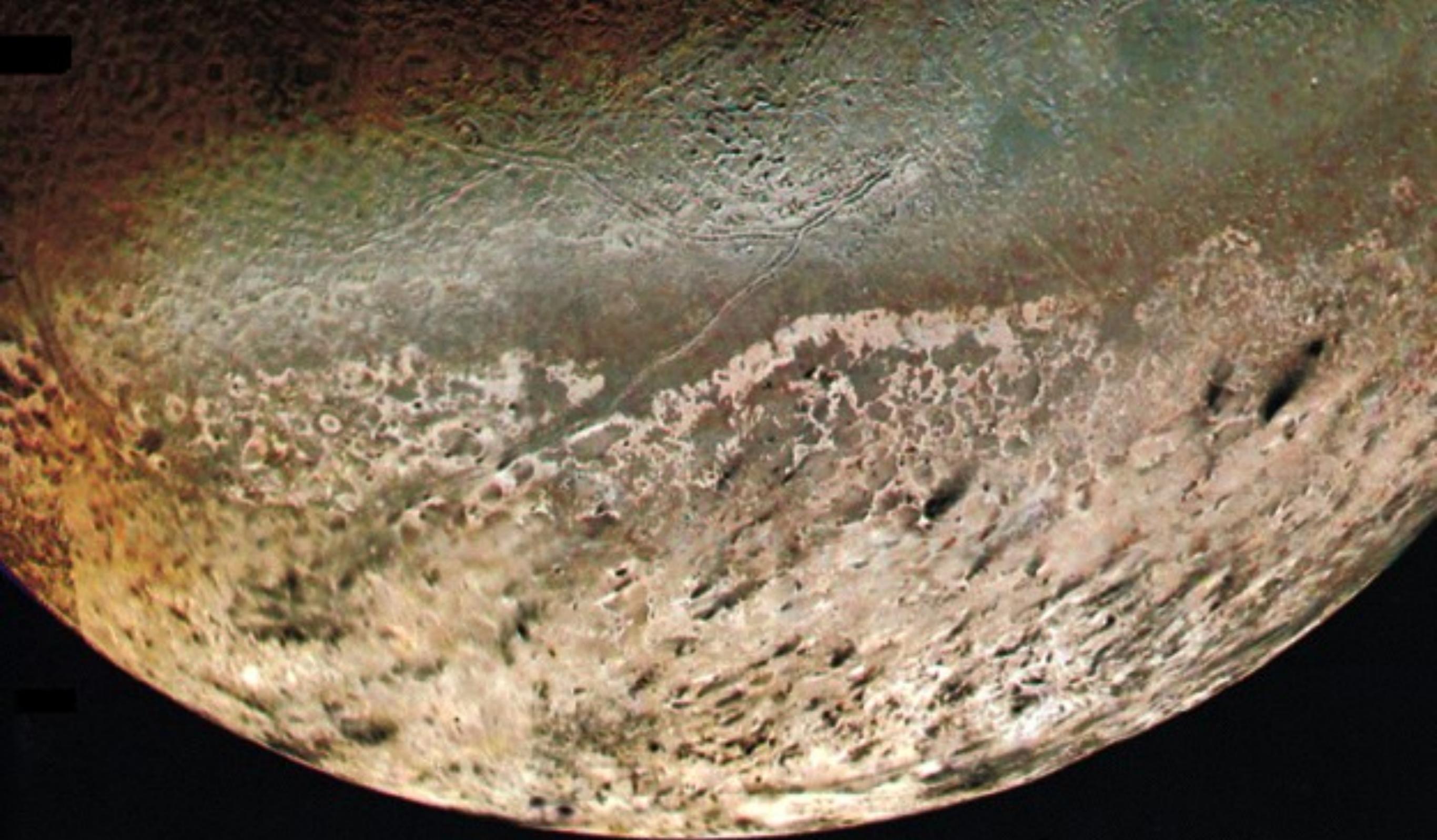
Uranus'  
odd moon  
Miranda



- Neptune has 14 moons
- The two largest moons have peculiar orbits.

- Nereid, about a tenth the size of Earth's moon, follows a large, elliptical orbit
- Triton, nearly 80 percent the size of Earth's moon, orbits Neptune backward—clockwise as seen from the north.



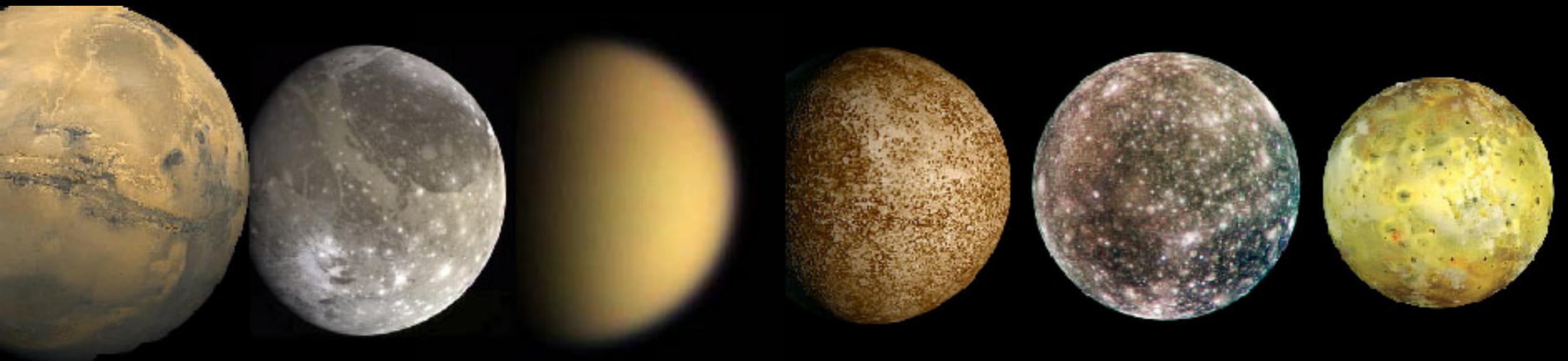


Neptune's largest moon, Triton, was probably captured by Neptune's gravity

# A few things to remember about the Galilean moons of Jupiter

- Callisto has no core- it seems to have frozen solid during its formation.
- Ganymede is the 9th largest object in the solar system! And yet it has no atmosphere.
- Despite having an icy crust, Europa may have an undersea ocean!
- Io has the highest level of volcanism in the entire solar system– exceeding that of Earth!

# Compare all the Moons of the Solar System



Mars  
6804.9 km      Ganymede  
5262 km      Titan  
5150 km      Mercury  
4879.4 km      Callisto  
4821 km      Io  
3643 km



Moon  
3476.2 km      Europa  
3122 km      Triton  
2706.8 km      Pluto  
2390 km      Sedna  
~ 1500 km      Titania  
1578 km      Rhea  
1528 km      Oberon  
1523 km      Iapetus  
1436 km      Quaoar  
1200 km



Charon      Umbriel      Ariel  
1186 km      1169.4 km      1158 km      Dione  
1118 km

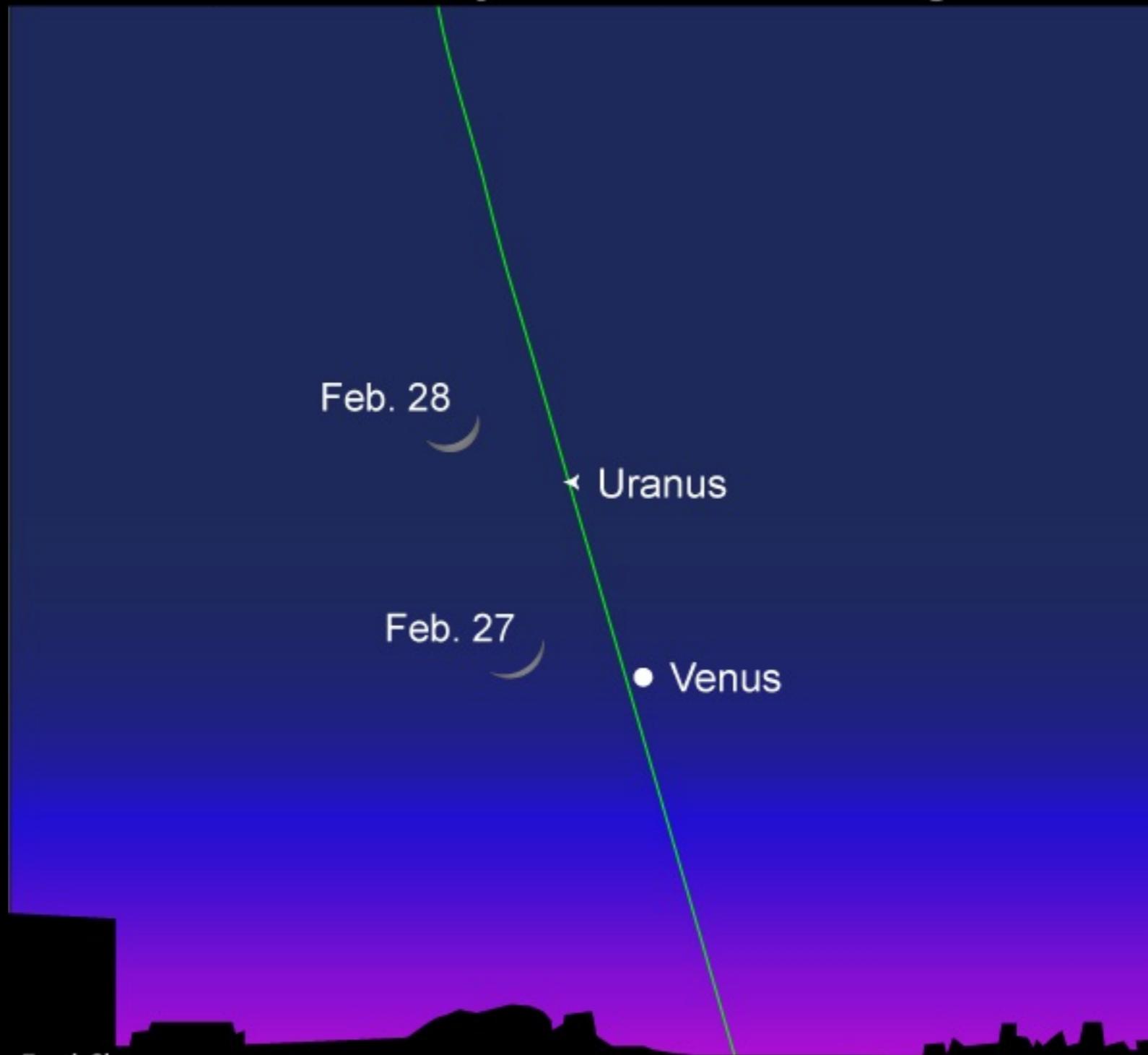


Tethys  
1059 km      Earth  
12,756.28 km

Diameters of the Terrestrial Bodies  
of the Solar System

# Back to our moon...

**West, February 2020, Dusk/Nightfall**



# Announcements

Exam #3 next Wednesday!

Review will be on Tuesday.

Lecture as usual on Monday.